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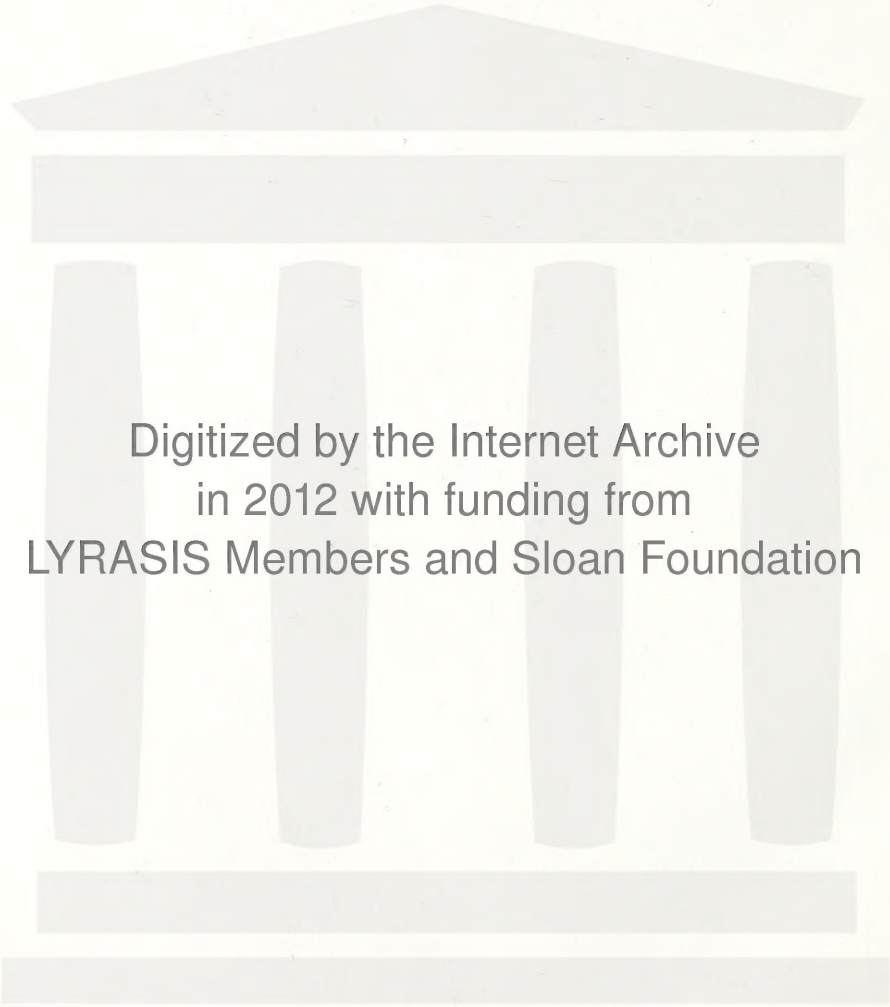
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Bloomington, Indiana

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Indiana University-Purdue University at Fort Wayne
Fort Wayne, Indiana

•

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Indiana Academy of Science
SPRING MEETING
OF THE EXECUTIVE COMMITTEE
April 22, 1983

MINUTES

The meeting was called to order by President Alice S. Bennett at 4:15 p.m. in Room 21-21A Walb Memorial Union, on the campus of Indiana University-Purdue University at Fort Wayne.

Minutes of the October 29 meeting were not available. It was moved that their approval be deferred until the Fall meeting.

TREASURER'S REPORT

Treasurer Duvall A. Jones reported Academy finances as of 21 April 1983:

Current Assets

Checking Account	$ 6,120.22
Savings Accounts	$18,453.06
Total	$24,573.28

These are distributed in

Academy Accounts	$ 9,056.41
Administered Accounts	$15,516.87
	$24,573.28

1983 income to date has been	$11,053.26
1983 expenditures to date are	$ 6,232.33

Acceptance of the report was moved, seconded, and carried.

REPORTS OF ELECTED COMMITTEES

Academy Foundation Committee

William A. Daily, chairman, reported that as of 31 March 1983 the John S. Wright Fund has a market value of $599,553. The John S. Wright Investment Income Account holds $108,000 available for use, primarily for research grants. The Academy Foundation account has a market value of $36,685.

Bonding Committee

No report needed at this time.

Research Grants Committee

Ernest E. Campaigne, chairman, reported that the committee had received 25 research applications, totalling nearly $24,000. The average request was for $960, with three requesting more than the $1500 limit set by the Academy. The total amount granted was $10,743; the average award was $565. Of the 25 applications, 6 were fully funded, 13 were partially funded, one was withdrawn, and 5 were not funded. A list of the approved applications and amounts granted follows, at end of minutes.

REPORTS OF APPOINTED COMMITTEES

Program

Co-Chairman Douglas Lyng and James Haddock reported that at the Fall meeting the Friday afternoon program will include a symposium on chemical demonstrations. The American Chemical Society is providing travel funds for the speakers. The Saturday morning program will center on acid rain, ground water pollution, and hazardous waste.

Youth Activities

Susan M. Johnson, chairman, presented the following report:

"At the meeting of the committee on February 22, 1983, in Indianapolis during the Hoosier Association of Science Teachers Conference, a major item of discussion was how to involve more high school and middle school students in Academy sponsored programs. This fall, the Junior Academy meeting will again take place on a state-wide teacher study day. In order to get more high school teachers to attend and bring students, the committee will ask that the Academy Meeting be listed as a suggested ISTA teacher education activity. The committee also recommended that the Academy President write to public school superintendents and administrators of private schools to inform them of the Junior and Senior Academy meetings.

With the goals of encouraging high quality science and, at the same time, attracting more students from more schools to participate in the Junior Academy, plans are underway to modify the meeting format of the Junior Academy. The modification includes a spring meeting, the first of which will be held on April 30, 1983. The spring meeting will include field trips and other hands-on science learning activities. Student participation will not require prior research and scholarly preparation. The Fall meeting will continue to feature presentation of research papers by students. A chance for junior members to hear about senior level research is also planned for the fall meeting.

At this time, winners of regional science fairs have been selected, and those students, advisors, and regional fair directors who plan to attend the International Science and Engineering Fair on May 9-14 in Albuquerque, New Mexico, have made reservations with Karl Kaufman. In order to facilitate the fund-raising efforts of regional science fair directors, the Academy is supporting production of a science fair brochure. Lloyd Anderson is doing this work. The plan is to deliver the brochure to regional directors by the fall, so that the directors can distribute brochure copies to potential contributors.

Under the leadership of Walter Cory, 47 high school juniors and seniors participated in the Indiana Science Talent Search. Fifteen students were introduced as winners at the awards luncheon on March 12, 1983, at the Student Union of IUPUI. The Academy was represented officially by Alice Bennett and Duvall Jones. Susan Johnson represented the Youth Activities Committee.

In other business, the Youth Activities Committee approved a motion that Keith Hunnings, former Director of the Junior Academy, be recognized for his work. The motion was forwarded to the President."

Chairman Johnson moved that the amount allocated for production of the brochure for science fair directors be increased from $400 to $600. Discussion of the motion brought out that although the Academy does not sponsor science fairs, it does foster them, and this brochure should be helpful. The motion carried.

Walter Cory spoke to the value of the Science Talent Search to the students and teachers involved. Winners are automatically members of the Academy for one

year, and several continue their membership. Science fair winners also are eligible to apply for scholarships through an interview process.

Junior Academy of Science

Leota Skirvin, director, was unable to attend. Her report was presented by Susan Johnson.

The trophy for "Best Overall School" has been eliminated because it generated unhealthy rivalry.

The Spring meeting is to be held April 30 at Brown County High School in Nashville. The theme will be "Caves" and it will include an afternoon of spelunking. Susan Johnson will lead a workshop on inspiring students to do research. Several awards will be announced.

Library

Lois Burton, chairman, was unable to attend. Her report was presented by William Daily.

Volume 91 of the *Proceedings* has not yet been received from the binder. It will be distributed immediately upon being received.

The "Requisition for Printing" for Volume 92 was prepared for the Editor and submitted March 29 to the Department of Administration. The amount paid from the allotment for 1983-84.

Notification has been received from the State Budget Agency that the state funds for printing of the *Proceedings* for 1983-84 will be $8400, and for 1984-85 will be $8900.

Editor

Donald R. Winslow, Editor, reported that Vol. 91 of the *Proceedings* is at the binder.

Publications

William R. Eberly, acting for Benjamin Moulton, chairman, reported that copies of *Ectoparasites of Indiana* are available.

The next publication will be the *History of the Indiana Academy of Science* being prepared by William and Fay Daily. Eberly suggested it be printed for free distribution.

Climate of Indiana is in progress.

Butterflies of Indiana will not be complete for several years. It is to include photographs of all Indiana butterfly species.

Relations of Academy to the State

Alice S. Bennett reported for Robert Henderson, chairman. President Bennett has written to Lieutenant Governor John M. Mutz welcoming him to membership in the Academy and informing him of the existence of this committee and the hope that it and his office will find ways to work together.

Invitations

Invitations are needed for meeting sites for 1986 and beyond.

Parliamentarian

No report. President Bennett spoke of the need for a review of the Constitution and By-laws. See discussion under "Old and New Business."

Preservation of Natural Areas

Marion T. Jackson, chairman, was unable to attend. His report was presented by Alice Bennett. The committee's two active concerns are:

Developing a standardized inventory methodology for natural areas that can be used by a number of field workers across the state.

Exploring ways to better utilize the diverse talents of IAS members with natural areas interests to help natural areas professionals (e.g., Division of Nature Preserves, Indiana Natural Heritage Program, and The Nature Conservancy.)

Emeritus Membership

Robert H. Cooper, chairman, sent a report nominating the following persons for Emeritus membership:

Robert M. Brooker	1951-1982	32 years
Harold D. Caylor	1931-1982	52 years
Margaret Fulford	1929-1982	54 years
Keith Hunnings	1954-1982	29 years
Willis H. Johnson	1928-1982	55 years
Preston McGrain	1940-1981	42 years
Frank Streightoff	1954-1981	28 years

Election to Emeritus membership was moved, seconded, and carried.

Biological Survey

Reporting for John A. Bacone, chairman, Theodore J. Crovello said that the committee is planning publication, as a Centennial volume, of a summary of information on biota and the environment.

OLD AND NEW BUSINESS

Registration Fee for Meetings

Duvall A. Jones moved the following Amendment to the Academy By-Laws:

Article XII
Registration Fee for Meetings

Section 1. Registration fees for Spring and Fall meetings of the Academy shall be determined annually by the Executive Committee (at the annual meeting).

Section 2. Honorary, Emeritus, and Life members shall be exempt from registration fees.

Section 3. Registration fees may be collected by the host institution, but must be transmitted to the Treasurer of the Academy for disbursement.

Jones explained the need for such a fee due to escalating costs. In response to a question, President Bennett said that even if the host institution did not request reimbursement, the Executive Committee should set a non-zero fee to build up an account for funding meetings.

The motion was seconded and carried.

Development Fellowship for Secondary-School Science Teachers

Ernest Campaigne reported on the current status of this project, which has been fostered by the Research Grants committee. The Fellowship would provide to the teachers $120 per week for 8 to 10 weeks, and to the sponsor up to $300 for materials. One or two teachers will be sponsored this year on a trial basis; then outside help, such as NSF, will be sought. A separate committee, under the chairmanship of Walter Cory, has been named to review applications and to oversee the program.

Operations Manual

Duvall Jones distributed without discussion drafts for statements of the duties of Section Chairperson, Program Requirements for Meetings, and Program Chairperson.

Publication of Saturday Meeting Presentations

President Bennett reported the suggestion of the Academy Council that transcripts of the Saturday morning symposia be published and distributed as a separate publication of the Academy. William Eberly said there was ample precedent for special publications. There was objection from the floor to funding such a project outside the regular budget procedure. Walter Cory suggested that the topics of Saturday meetings are within the purview of the Science and Society Committee, and perhaps that committee would have time and funds to pursue the matter.

Constitutional Review

Copies of the Constitution of the Academy appear in the *Proceedings* for 1964 and 1980, but it is not clear that all Amendments voted at intervening meetings are in operation. The matter needs study by a special committee. The President will pursue the matter.

ANNOUNCEMENTS

Changes in Committee Directory

Geology and Geography Section—Gerald Showalter has resigned as chairperson-elect.

Preservation of Natural Areas Committee—add William Weeks, State Director Indiana Chapter, The Nature Conservancy.

"Speaker of the Year" Selection Committee—Donald Gray has resigned as Chairman

Youth Activities Committee—add John A. Ricketts, Department of Chemistry DePauw University

Academy Telephone

The Academy has no central office, but general calls may be handled by Mrs. Lois Burton at the Indiana State Library, 317/232-3686

ADJOURNMENT

The meeting was adjourned at 6:35 p.m.

Respectfully submitted,

Richard L. Conklin
Secretary

Indiana Academy of Science
Spring, 1983, Grant Applications Funded
Research Grants Committee Actions

No.	Principal Investigator/ Institution	Title	Funded
1	Mohammad Behforouz Ball State University	Heterocyclic Synthesis: Lavendamycin and Other Pyridine Derivatives	$ 1,100
2	Bartholomew G. Corsaro University of Notre Dame	Role of Imaginal Disc Cell Death in Expression of the Eyeless Mutant of *Drosophila melanogaster*	$ 350
3	Christine Dougherty Ball State University	Determination of Nitrogen and Sulfur Content of Radish Plants Exposed to Simulated Acid Rain	$ 139
4	Mary Ann K. Hughes Indiana University	Thermoregulation in *Sternotherus odoratus*: Behavior and Ecology	$ 330
5	Austin L. Hughes Indiana University	Seasonal Trends in Adult Male Life History in the Western Mosquitofish and their Adaptive Significance	$ 375
6	Mary L. Jaynes University of Notre Dame	Effects of Submersed Plants on Lake Sediment Redox and Solute Profiles	$ 700
7	Richard J. Jensen, Ph.D. Saint Mary's College	Patterns of Variation Within and Between Two Indiana Red Oaks	$ 475
8	Kenny Lipkowitz Indiana University-Purdue University at Indianapolis	Symposium on Molecular Mechanics	$ 500
9	James R. Lovvorn and Charles M. Kirkpatrick Purdue University	Vigilance and Flock Edge Affinity of Sandhill Crane Family Groups	$ 500
10	Michael J. Mandracchia University of Notre Dame	Glochidium Larva: Its Role in the Ecology and Evolution of Freshwater Clams	$ 475
11	Molly Morris Indiana University	Call Order and Call Site in Relation to Female Choice: A Study of Anuran Mating Behavior	$ 669
12	William E. Nellist Indiana University	Large and Small-Scale Cyclicity in the Kokomo Limestone Member of the Wabash Formation	$ 400
13	William J. Rowland Indiana University	An Experimental Investigation of Releasing Mechanisms in the Threespine Stickleback, Gasterosteus aculeatus	$ 760
14	Raymond J. Russo Indiana University-Purdue University at Indianapolis	The Hormonal Basis of a Change in Predation Behavior of Toxorhynchites, a predator on container-breeding mosquitoes	$ 860
15	Robert J. Stark DePauw University	A Study of Transmembrane and Transcellular Ion Transport during Stimulus-Secretion Coupling in the Salivary Gland	$ 740

16	Licia Wolf Indiana University	Biparental Care in the Monogamous Dark-eyed Junco: Testing an Assumption	$ 600
17	Robert James Autio Indiana University	Glacial Lakes Quincy and Eminence Stratigraphic Study	$ 420
18	Steve Gilbert Purdue University	Use of Analogy in Promoting Achievement in High School Biology	$ 600
19	Catherine Zmachinski Ball State University	Investigation of the Relationship Between Testosterone and Dominance in Male Syrian Golden Hamsters	$ 750
		Total	$10,743

Indiana Academy of Science
MINUTES OF THE ACADEMY COUNCIL
October 27, 1983

The Council of the Indiana Academy of Science met at Ted Gouloff's Restaurant, 3311 N. Anthony Blvd., Fort Wayne, on Thursday, October 27, 1983.

The meeting was called to order by President Alice S. Bennett at 3:20 p.m. Council members present were Dr. Bennett, Duvall Jones, Theodore Crovello, Donald Winslow, Walter Cory, Douglas Lyng, James Haddock, Benjamin Moulton, and Richard Conklin.

President Bennett announced appointment of a new nominating committee: J. Dan Webster, chair; William Eberly, and John Patton.

In preparation for a change of officers, the President suggested that all Council members gather information on deadlines for action by the officers. She will ask at the Executive Committee meeting that each committee chair do likewise.

The program chairs raised two matters of concern: Slow delivery of bulk mailings is a problem. The laboratory equipment display was cancelled. Since the displayers had agreed to provide some fund for coffee, this raised the question of whether program chairs in the future should solicit funds for coffee and list in the program names of sponsors.

At the time of the vote on the constitutional amendment authorizing registration fees, Council will suggest the following fee schedule for the Fall meeting:

$5.00 Members, except those specifically exempted
$7.00 Non-members
$2.00 Students

Council will suggest to the committee studying the constitution that additional chairs (e.g., Publications Committee) be added to the membership of the Council.

Minor publications, such as pamphlets and list of speakers, should be managed by the Publications Committee. The speakers bureau list has been published by the Director of Public Relations with the understanding that his budget would be reimbursed, perhaps from Science and Society or the President's Fund. New Academy brochures are needed. Cory will prepare a design and circulate it to Council.

Cory announced that both winners of Secondary School Teacher Fellowships will be presenting papers at their sections of the meeting.

Dr. Robert Fischer of Ball State Department of Psychological Sciences has received positive response from several persons around the state concerning reactivation of the Psychology Section. Council granted approval, and it will be taken to the Executive Committee for final approval.

There was considerable discussion about a resolution stating the Academy's position on elementary and secondary science education. It was decided that Jones and Bennett would prepare such a resolution to be presented to the membership at the General Meeting. The essence of that resolution would be strong support of public education and possible reorganization of the educational structure in the state.

The meeting adjourned to dinner at 5:00 p.m.

Respectfully submitted,

Richard L. Conklin, Secretary

Indiana Academy of Science
FALL MEETING
OF THE EXECUTIVE COMMITTEE
October 27, 1983

MINUTES

President Alice S. Bennett called the meeting to order at 7:15 p.m. in Room 21-21A, Walb Memorial Union, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana.

Minutes of the Executive Committee meeting of April 22, 1983, were approved as corrected (Minutes of the Executive Committee meeting of October 29, 1982, approval of which was deferred at the Spring meeting, had already been approved at the October 30, 1982, General Meeting).

TREASURER'S REPORT

Treasurer Duvall A. Jones reported the Academy finances as of October 26, 1983:

Current Assets

Checking Account	$ 5,252.58
Savings Accounts	$18,422.56
Total	$23,675.14
These are distributed in	
Academy Accounts	10,203.49
Administered Accounts	13,471.55
Total	$23,674.14

Membership total as of October 26, 1983 was 954.

It was moved and seconded and voted that the treasurer's report be accepted.

REPORTS OF ELECTED COMMITTEES

Academy Foundation Committee

William A. Daily, chairman, reported that on September 30, 1983, the Foundation Account had a market value of $40,796 and had earned $2,688.85 during the past year. The John S. Wright Fund had income of $37,056.22, all of which was transferred to the Invested Income account. The Fund had a market value of $731,483.00. The Invested Income Account earned $13,677.95 in the same period and had assets of $109,295.81 as of September 30, 1983.

Bonding Committee

No report necessary at this time.

Research Grants Committee

Ernest E. Campaigne, chair, announced that Academy Research Grants in the amount of $9550 and Secondary School Research Grants totaling $1,036 had been approved in the Fall round. A list of those grants is appended at the end of these minutes.

Walter Cory described the new High School Fellowship program for teachers, and announced that the two recipients of these fellowships this year will be presenting papers in their respective sections. They are Cynthia K. Brown of Angola and Arthur Middleton of Rensselaer.

REPORTS OF STANDING COMMITTEES

Program

Co-chair R. Douglas Lyng and James Haddock reported on details of the Fall meeting.

Auditing

No report at this time.

Youth Activities

Susan Johnson, Chair, reported that the Indiana Science Talent Search, directed by Walter Cory, is in its 37th year of operation. Brochures and entry forms have been sent to all senior high schools in Indiana. Finalists will be interviewed and honored at an awards luncheon in Indianapolis on March 10. Kappa Kappa Kappa sorority is sponsoring the competition and is awarding two $1,000 scholarships. Dr. Cory distributed a brochure and report of finalists in the 1982-83 Search.

The number of students who participated in regional science fairs increased last Spring, and thirty students from Indiana received awards at the International Science Fair. A brochure for science fair directors will be available in January.

Teacher workshops are being offered to help increase the quantity and quality of high school research. One thousand dollars of the money awarded for high school research was provided by a grant from the AAAS.

Junior Academy of Science

Leota Skirvin Smith, Director, announced that the second Spring meeting of the Junior Academy will be held at Hammond and will feature the ecology of the dunes. There have been some changes in format at the Fall meeting to avoid having competitions taking place during the paper presentations.

The practice of awarding a year's membership in the AAAS to the outstanding junior scientist in the senior division has been reinstated.

Library Committee

Volume 91 of the *Proceedings* has been distributed to Academy members and science clubs. Copies of the *Proceedings* and Monograph Number Four were distributed to approximately 500 libraries, institutions, and societies.

The requisition for printing of Volume 92 of the *Proceedings* was prepared for the Editor and presented to the Department of Administration on March 29. The 1983/84 state appropriation of $8400 for printing Volume 92 has been encumbered.

Publications Committee

Benjamin Moulton, chair, distributed the report. The first draft of the Daily volume on the History of the Academy is complete and is being reviewed. *The Climate of Indiana* is in progress.

The committee is considering means for formalizing procedures for acquiring budgeting, and distributing monographs.

Committee on Fellows

Wilton S. Melhorn, chair, presented the names of six persons to be placed in nomination at the General meeting. They were approved for recommendation to the membership as candidates for the rank of Fellow.

There was some discussion of the qualifications for Fellows, and the possibility of making them more specific when the Constitution is revised.

Committee on Emeritus Members

Robert I. Fletcher of Greencastle, IN, was granted Emeritus Membership.

Representative to Natural Resources Commission

A brief report sent by Damian Schmelz, the present representative, described the responsibilities of the Commission and reminded the Academy that its representative brings the only input from the professional scientific community.

Editor

Donald Winslow, Editor, reported that Volume 91 of the *Proceedings* was printed by Western Newspaper Publishing Company, Inc. of Indianapolis. Eight hundred hard bound and 525 paper bound copies of 700 pages each, including the cumulative index were printed at a cost of $8,000 to the State and $10,896.50 to the Academy.

The same company will print Volume 92. Delivery date is scheduled for December 15, 1983.

Volume 93 is in preparation. A set of guidelines has been prepared to help the Editorial Board identify the outstanding research papers submitted for publication.

Speaker of the Year

Ernest E. Campaigne, Professor of Chemistry, Indiana University, is Speaker of the Year.

Centennial

Walter Cory reported that the Spring meeting in the Centennial Year will be held in Brookville on April 27-28 and the Fall meeting at Butler University on October 26-27. Several program sections are encouraged to feature their histories at the Fall meeting.

Constitutional Revision

William Eberly, chair, reported that the Committee hopes to have suggestions ready for discussion at the Spring meeting, and final action at the Fall meeting.

Chairs of all committees were requested to prepare outlines of their duties, schedules, etc., and send them to President-Elect Crovello.

Resolutions

William Davies, chair, moved approval of a resolution of appreciation he will present at the General Session. The motion was seconded and carried.

Duvall Jones discussed the present status of elementary and secondary education in Indiana. He proposed a resolution to be presented to the membership at the General meeting. J. Dan Webster moved that the Executive Committee approve the first two portions of the three-part resolution. The motion was seconded and carried.

Nominating

J. Dan Webster, chair, reported the slate of officers who will be presented to the Academy for election at the General meeting. His motion to nominate these people was seconded and carried.

OTHER BUSINESS

Psychology Section

Robert Fischer of the Department of Psychological Sciences at Ball State University, has requested that the Psychology Section of the Academy be reactivated. He has submitted some thirty-five petitions expressing interest in such a section

and has agreed to chair it for the first year. Theodore Crovello moved reactivation of the Psychology Section of the Academy. The motion was seconded and carried.

Registration Fee

At the General Meeting the membership will be asked to vote on a constitutional amendment empowering the Executive Committee to establish registration fees for the Spring and Fall meetings.

Duvall Jones moved that if that amendment is passed, the fees for the Fall meeting, 1984, be $5.00 for members not exempted in the amendment, $7.00 for non-members, and $2.00 for students. There would be no fee for the Spring, 1984, meeting. The motion was seconded and carried.

Adjournment: 10:00 p.m.

Respectfully submitted,

Richard L. Conklin
Secretary

Indiana Academy of Science
Fall, 1983, Grant Applications Funded
Research Grants Committee Actions

No.	Principal Investigator/Institution	Title	Funded
1	G. P. Alberici Notre Dame	Response of Ascending Auditor Fibers of the Cricket. . .	$ 350
2	T. L. Derting Indiana University	Basal Metabolic Rate, Thyroid Gland Activity, and Assimilated. . .	680
3	K. W. Eberly Saint Mary's College	Skin Microflora of the Indiana Red Squirrel. . .	600
4	Dr. J.D. Haddock Indiana University-Purdue University at Fort Wayne	The Effect of Prey Diet on Predation Efficiency of the Coccinellid, . . .	510
5	J.H. Jones Indiana University	A Leaf Architectural and Cuticular Analysis of Extant Rhamnaceae	612
6	W.L. Kovach Indiana University	Dispersed Plant Remains from the Cenomanian of Kansas: . . .	680
7	M.P. Kowalski	The Effect of Nest Parasites on the Growth and Survivorship of. . .	210
8	Vicki J. Martin Notre Dame	The Role of the Nervous System in Metamorphosis of Cnidarian. . .	650
9	Marsha Lakes Matyas Purdue University	Prediction of Achievement and Attrition among Male and. . .	730
10	R.O. McCracken Indiana University-Purdue University at Indianapolis	The Effect of Single and Divided Dose Administration on the Efficacy of. . .	775
11	Eric Mould St. Mary's College	Effects of Phenolics on Forage Utilization by Monogastric. . .	445
12	Cheryl Ann Niemi Ball State University	Pupillary Diameter as a Psychophysiological Marker of Vulnerability. . .	405
13	I. Okonkwo Purdue University	Engineering Geology Evaluation of an Earth Rock-Fill Dam in an. . .	650
14	R.J. Olsen Wabash College	Fragmentation Reactions of Trimethylene Sulfites	700
15	C.M. Rogers Indiana University	Genetic and Environmental Components of Winter Fat stores in a. . .	640
16	J.C. Schumm Purdue University	The Relationship Between Student Locus of Control Orientation and. . .	413
17	E.M. Shull N. Manchester, IN	The Butterflies of Indiana	500
		TOTAL. . .	$9,550

Fall 1983

Secondary School Research Grants

No.	Name/School/Sponsor	Title	Funded
1	Loretta M. Baker East Noble H.S. Virginia Rhodes	Studies on Gossypol: II. Antifertility Effects in Nutritionally Deprived Rats	150
2	Thomas Barker East Noble H.S. Virginia Rhodes	Recovery and Identification of Viruses from Wastewater Sludge	115
3	Matt Booty John Adams H.S. Nevin Longenecker	Possible Effects of an Induced Magnetic Field on *Staph. epidermis*	93
4	Ted Couillard Highland Senior H.S. Mrs. Cheryl Mason	Physiological Effects of Fluoride Concentration on *Azo. chroococcum*	75
5	Julie Goldmann The GAGE Institute Matthew J. Goldberg	Effects of Psychological Stress upon Rate and Extent of Tumor Growth	120
6	Betsy Killeen John Adams H.S. Nevin Longenecker	Study of Biochemical Changes Underlying Behavioral Modification Associated with Ingestion of Caffeine and Acetylsalicyclic Acid	48.50
7	Mary Kudrak Northwestern H.S. Mrs. Patricia Zeck	Effects on Hidden Sodium on the Heartbeat of *Daphnia*	98
8	Derek Lannuier John Adams H.S. Nevin Longenecker	The Possible Effects of Valium on the Immunosuppressive Response to Audiogenic Stress in Laboratory Mice	66.50
9	Dawn J. O'Connor East Noble H.S. Virginia Rhodes	Comparative Study of Androgens and Anabolic Steroids in Relation to the Immune Response	95
10	Mark D. Owens Marquette H.S. Dean Christakis	Holographic Interferometry: Measurement of Pressure-Mediated Nanometric Movement as Applied to Industrial Bearings	95
11	Kathleen Ramos Donald G. Gavit H.S. Michael Kobe	Effects of Cigarette Smoke on Nasal Bacteria	80
		TOTAL . . .	$1,036

Indiana Academy of Science
October 29, 1983
MINUTES OF THE GENERAL MEETING

The General Meeting of the Indiana Academy of Science was called to order by President Alice S. Bennett at 1:15 p.m. on Friday, October 29, 1983, in the Classroom-Medical Building 159 at Indiana University-Purdue University at Fort Wayne.

Dr. James Bundschuh, Dean of Science and Humanities, welcomed the Academy on behalf of the universities.

President Bennett made several housekeeping announcements.

Secretary Richard L. Conklin reported on the 1983 meeting of the Executive Committee. A motion to accept the report carried.

Dr. J. Dan Webster, Nominating Committee chair, moved the election of the following persons as officers and members of elected committees for 1984:

President: Theodore S. Crovello
President-Elect: Benjamin Moulton
Academy Foundation Committee: William A. Dailey (2-year term)
John A. Ricketts (1-year term)
Bonding Committee: Mary Lee Richeson (2-year term)
Donald Hendricks (1-year term)
Research Grants Committee: James E. Newman (5-year term)

A motion to approve the report of the Nominating Committee was seconded and carried. A motion that those nominated be declared elected unanimously was seconded and carried.

Dr. Wilton S. Melhorn, Fellows Committee chair, moved that the following persons who had been approved by the Executive Committee, be elected to the rank of Fellow:

Jack L. Albright, Purdue University
James H. Kellar, Indiana University
Victor L. Riemenschneider, Indiana University, South Bend
Gary C. Steinhardt, Purdue University
Terry R. West, Purdue University
Eliot C. Williams, Wabash College

The motion was seconded and carried. Congratulations and certificates of recognition were extended to those newly-elected Fellows who were present.

Fay Kenoyer Daily, Necrologist, reported the deaths of four Academy members whose deaths had been recorded during the past year:

Roderic Malcolm Koch
B. Elwood Montgomery
Eberhard Hopf
Herman George Wilhelm, Jr.

Treasurer Duvall Jones presented the following amendment to the Constitution of the Academy:

Article XII
Registration Fees for Meetings

Section 1. Registration fees for Spring and Fall meetings of the Academy shall be determined annually by the Executive Committee (at the annual meeting).

Section 2. Honorary, Emeritus, and Life members shall be exempt from registration fees.

Section 3. Registration fees may be collected by the host institution, but must be transmitted to the Treasurer of the Academy for disbursement.

A motion to adopt the amendment was made, seconded, and carried without a dissenting vote.

Dr. William Davies, Resolutions Committee chair, proposed the following resolution:

WHEREAS: The Indiana Academy is deeply grateful to Indiana University-Purdue University at Fort Wayne for its invitation to hold its 99th annual meeting on their campus; and

WHEREAS: The administration, faculty, and students alike have cooperated in providing us their facilities for this meeting; be it

RESOLVED: That the Academy members here assembled express their sincere appreciation to Dr. Joseph P. Giusti, Chancellor of Indiana University-Purdue University at Fort Wayne, for all the courtesies that have been extended to the Academy during this meeting. We are especially grateful to Dr. James D. Haddock and Dr. Robert D. Lyng and their committee for the arrangements of the entire program and the comfort and conveniences provided the membership. We also express our sincere thanks to all members who organized and participated in the special symposia "Groundwater and Hazardous Waste Management," "Acid Rain," and "Chemical Demonstration Symposium."

The resolution was adopted unanimously.

Dr. Davies moved adoption of a second resolution:

WHEREAS: There is a recognized need to establish a vigorous program for the improvement of science education in Indiana; and

WHEREAS: State agencies are attempting to develop a strong state Board of Education which can exercise leadership in developing more effective programs in science education; and

WHEREAS: The Indiana Academy of Science is directed, constitutionally, to improve education in science in Indiana; be it

RESOLVED: That the Indiana Academy of Science commend the Indiana Commission of General Education and the Governor for setting higher standards for graduation from high school, which include two years of natural sciences, be it further

RESOLVED: That the Indiana Academy of Science strongly urge that three years of natural sciences (including both physical and biological sciences) be required for high school graduation.

Dr. Jones moved the following amendment:

BE IT FURTHER RESOLVED: That the Indiana Academy of Science provide appropriate leadership in the development of effective statewide programs for improving in the scientific expertise and scientific literacy of Indiana citizens of all ages.

The amendment and the main motion were seconded and carried without a dissenting vote.

The meeting adjourned at 2:05 p.m.

Respectfully submitted,

Richard L. Conklin, Secretary

Immediately following the meeting Dr. Ernest Campaigne presented his address as Speaker of the Year, "Drugs and the Mind."

During the afternoon a symposium on lecture demonstrations in chemistry was presented before large and appreciative audiences.

On Saturday morning the Science and Society Committee, chaired by Dr. William Beranek, presented symposia on hazardous waste management, groundwater, and acid rain, which were attended by about fifty people, mostly Academy members joined by a few people from the Fort Wayne community.

Indiana Academy of Science
Budget Committee Meeting
December 10, 1983

Minutes

The 1983 meeting of the Budget Committee of the Indiana Academy of Science was called to order by President-elect Theodore Crovello at 10:00 a.m. Saturday, December 10, in the Medical Center Union Building, Indiana University-Purdue University, Indianapolis.

Present were Alice Bennett, Lois Burton, Richard Conklin, Walter Cory, Theodore Crovello, William Daily, Frank Guthrie, Uve Hanson, Susan Johnson, Duvall Jones, Benjamin Moulton, John Patton, Donald Winslow.

Crovello announced four committee appointments and assignments: Alice Bennett, will chair the Science and Society Committee. This committee will absorb the functions of the former committee on the relation of the Academy to the State. Frank Guthrie will chair a new *ad hoc* advisory committee on financial planning. Other members are William Daily, Duvall Jones, and John Ricketts. Walter Cory will chair the membership committee. Philip St. John will act as program chair for both the Spring and Fall meetings.

A proposed budget for 1984 was presented by the Treasurer. In a discussion of this budget, the following items were discussed and actions taken:

$600 was allotted to Membership for printing a new brochure
$100 was added to the Newsletter budget

The Centennial Committee allocation of $2,600 is subdivided as follows:

Space Rental (Brookville)	$ 150.00
Honoraria (Fall Meeting)	$1,000.00
Speakers' Travel	950.00
Speakers' Expenses	350.00
Misc. Administrative	150.00

(A one-page letter from the President detailing Centennial plans will accompany dues notices to be mailed in March.)

The Allocation to the Youth Activities Committee is $1,650:

Brochure for Science Fair Directors	$600.00
AAAS Grant Matching Funds:	
1983-1984	300.00
1984-1985	300.00
Recognition of pre-college science teachers	450.00

The new Finance Committee is budgeted $450.00 to pay legal, CPA, etc. fees. An increased fee by the CPA formerly employed resulted in a change to Blue, Inc., of Rensselaer.

The Junior Academy of Science was allocated $1,000:

Awards	$300.00
Travel Expenses	600.00
Administrative	100.00

This was moved from Administered accounts to Academy accounts.

The spirit of the registration fee recently approved by the Academy is that such money not spent on a given meeting should accumulate. Guthrie suggested that this money should be placed in the reserves to pay fees when needed.

Publication of the *History of the Academy* will be financed from the John S.

Wright fund. The *History* will be distributed free to all members. The price to non-members will be based on publication cost.

A request for $27,900 for publication of *Butterflies of Indiana* (5000 copies) was submitted by the Publications committee. Decision on this was delayed to the Spring meeting of the Executive Committee, at which time the Publications Committee should report its recommendations as to number of copies, distribution, and prices to members and non-members. Similar decisions must be made on the forthcoming *Climate of Indiana*.

Bennett suggested that the announcement of participants in the Speakers' Bureau be allocated $500 and another $2000 be authorized for publication of the proceedings of the Saturday morning symposium at the Fall meeting. No action was taken.

A special award for the best research paper in the *Proceedings* was funded by adding $300 to the budget.

The proposed budget was approved unanimously. The Treasurer will prepare copies of the budget as revised in this meeting and circulate them to those who need to see them.

The meeting adjourned at 12:35 p.m.

Respectfully submitted,

Richard L. Conklin
Secretary

Indiana Academy of Science

Financial Report
1 January - 31 December 1983

I. ACADEMY ACCOUNTS

	Income	Budgeted	Expenditures	Budgeted
Dues	$ 8,114.00	$ 8,000.00		
Reprints: Vol. 91	2,579.09	3,250.00	$ 2,445.50	$ 2,850.00
Vol. 92	456.90			
Interest	2,169.22	1,750.00		
Meal Tickets	25.00			
Secretary			315.33	600.00
Treasurer			585.56	600.00
General Office			247.53	250.00
Officer Honoraria			150.00	150.00
Membership Committee			144.66	400.00
President's Contingency Fund			185.00	225.00
Newsletter			800.00	800.00
Speaker of the Year			700.00	700.00
Program Committee			1,451.14	2,300.00
Editor's Expenses			700.00	700.00
Youth Activities Committee			0.00	600.00
Biological Survey Committee			0.00	1,000.00
Centennial Committee			0.00	200.00
AAAS Representative			250.00	250.00
Section Chairmen's Expenses			0.00	50.00
Public Relations			150.00	150.00
Research Grants			100.00	100.00
CPA Fees for Tax Returns			500.00	500.00
Miscellaneous			25.00	100.00
Transfers to Administered Accounts			2,450.00	2,450.00
TOTALS	$13,344.21	$13,000.00	$11,199.72	$14,975.00

II. ADMINISTERED ACCOUNTS

	January 1 Balance	1983 Transfers & Income*	1983 Expenditures	December 31 Balance
Junior Academy	$ 1,211.76	$ 0.00	$ 777.18	$ 434.58
Science Talent Search	619.18	2,577.00 (I)	2,747.94	948.24
		500.00 (T_1)		
Science & Society	1,447.89	0.00	152.80	1,295.09
Research Grants	-6,271.51	21,593.00 (T_2)	20,532.25	-5,210.76
Natural Areas	0.00	0.00	0.00	0.00
J.S. Wright Library Fund	134.28	0.00	0.00	134.28
Lilly III Library Fund	2,632.76	0.00	13.00	2,619.76
Lilly V Library Fund	4,500.20	0.00	0.00	4,500.20
Library Binding	1,500.65	1,500.00 (T_1)	0.00	3,000.65
Proceedings: Printing & Awards	1,589.89	8,892.00 (T_2)	8,529.00**	1,952.89
Proceedings: Mailing	756.87	450.00 (T_1)	656.78	550.09
Publications: Sales & Expenses	2,964.91	1,259.14 (I)	788.70	3,435.35
Research Fellowships	0.00	2,560.00 (T_2)	2,410.75	149.25
TOTALS	$11,086.88	$39,331.14	$36,608.40	$13,809.62

I: Income from external sources.

* T_1: Transfer from Academy Accounts. T_2: Transfer from Academy Trust Funds.

** The State of Indiana paid an additional $8,000.00 toward printing of the *Proceedings*.

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance: 1 January 1983	$ 8,665.17	$11,086.88	$19,752.05
1983 Income and transfers	13,344.21	39,331.14	52,675.35
1983 Expenditures and transfers	11,199.72	36,608.40	47,808.12
Balance: 31 December 1983	$10,809.66	$13,809.62	$24,619.28

IV. BANK BALANCE (as of 31 December 1983)

Super NOW Account	
Farmers and Merchants Bank, Rensselaer, IN	$ 5,656.39
Includes Interest for 1983—$313.81	
Savings Acccounts	
Farmers and Merchants Bank, Rensselaer, IN—CD #90007567	5,522.12
State Bank of Rensselaer, IN—CD #100208266	13,440.77
TOTAL	$24,619.28

V. SUMMARY OF TRUST FUNDS

A. Foundation Account (00430-00-0)

1. Income Account			
Income cash balance (1/1/83)		$ 0.00	
Dividends and interest of 1983		2,631.32	
Disbursements for 1983			
Research Awards	$ 300.00		
Investments purchased	900.00		
Transfer to Principal cash	1,431.32		
	$2,631.32	-2,631.32	
Income cash balance (12/31/83)		$ 0.00	$ 0.00
2. Principal Account			
Principal cash balance (1/1/83)		$ 291.67	
Total receipts for 1983		20,700.00	
Transfer from Income Account		1,431.32	
Total disbursements for 1983			
Investments purchased	$21,947.18	-21,947.18	
Principal cash balance (12/31/83)		$ 475.81	475.81
Market value of investments (12/31/83)			40,631.06
Total value of account (12/31/83)			$41,106.87*

* Carrying value of investments (12/31/83) is $33,728.68

B. John S. Wright Fund (00430-01-9)

1. Income Account			
Income cash balance (1/1/83)		$ 1,512.50	
Dividends and Interest for 1983		36,291.28	
Investments sold		22,900.00	
Disbursements for 1983			
Commission and fees	$ 3,828.00		
Miscellaneous expenses	33,975.78		
Investments purchased	22,900.00		
	$60,703.78	-60,703.78	
Income cash balance (12/31/83)		$ 0.00	$ 0.00
2. Principal Account			
Principal cash balance (1/1/83)		$ 20,009.77	
Total receipts for 1983		72,300.00	
Total disbursements for 1983		-92,307.58	
Principal cash balance (12/31/83)		$ 2.19	2.19
Market value of investments (12/31/83)			692,425.09
Total value of account (12/31/83)			$692,427.28*

* Carrying value of investments (12/31/83) is $316,759.37

C. J.S. Wright Invested Income Account (00430-02-8)

1. Income account		
Income cash balance (1/1/83)	$ 5,925.00	
Total interest for 1983	9,251.32	
Disbursement for 1983		
Investments purchased	-4,500.00	
Research Fellowships	-2,560.00	
Transfer to Principal Account	-8,116.32	
Income cash balance (12/31/83)	$ 0.00	$ 0.00
2. Principal Account		
Principal cash balance (1/1/83)	$ 34,890.34	
Total receipts for 1983	200,543.28	
Disbursements for 1983		
Investments purchased	-206,885.23	
Distributions (Grants & *Proceedings*)	- 31,189.50	
Transfers from Income Account	8,116.32	
Principal cash balance (12/31/83)	$ 5,475.21	$ 5,475.21
Market value of investments (12/31/83)		104,785.23
Total value of account		$110,260.44

VI. NOTES

Membership as of 31 January 1984: The Treasurer's records show that the Academy has 1060 paid memberships for 1983: 38 sustaining, 2 sustaining family, 510 senior, 27 senior family, 272 regular, 11 regular family, 71 students, 108 emeritus, 2 honorary, 3 life, and 16 club memberships.

3 members deceased (included in totals above).
124 members on file from 1982, but not paid for 1983.
112 new members for 1983 (included in totals above).
5 previous members reinstated in 1983 (included in totals above).
5 persons resigned.
89 individuals dropped for nonpayment of 1982 dues.

Dues structure for 1983:

$ 2.00	for student memberships
5.00	for memberships and club memberships
10.00	for senior memberships
25.00	for sustaining memberships
2.00	additional for family memberships
300.00	for life memberships
150.00-500.00	corporate memberships
50.00-100.00	institutional memberships
1.00	initiation/reinstatement fee ($2.00 for family membership)

Reprints: All authors of papers in Volume 91 of the *Proceedings* have paid for the reprints which they ordered. Cost of the reprints to the Academy was $2,445.50. Authors paid the Academy $2,579.09 for reprints.

Publications: Sales of reprints, monographs and *Proceedings* in 1983 totaled $1,259.14.

Research Grants: Funds totalling $21,329.00 have been awarded to: M. Behforouz (Ball State U.), B. G. Corsaro (Notre Dame), C. Dougherty (Ball State), M. K. Hughes (Indiana U.), A. L. Hughes (Indiana U.), M. L. Jaynes (Notre Dame), R. J. Jensen, (St. Mary's C.), K. Lipkowitz (IUPUI), J. R. Lovvorn & C. M. Kirkpatrick (Purdue U.), M.J. Mandracchia (Notre Dame), M. Morris (Indiana U.), W.E. Nellist (Indiana U.), W. J. Rowland (Indiana U.), R.J. Russo (IUPUI), R.J. Stark (DePauw U.), L. Wolf (Indiana U.), R.J. Autio (Indiana U.), S. Gilbert (Purdue), C. Zmachinski (Ball State U.), G.P. Alberici (Notre Dame), T.L. Derting (Indiana U.), K.W. Eberly (St. Mary's C.), J.D. Haddock & J.K. Averback (IUPU-Fort Wayne), J.H. Jones (Indiana U.), M.P. Kowalski, V.J. Martin (Notre Dame), M.L. Matyas (Purdue U.), R.O. McCracken (IUPUI), E. Mould (St. Mary's), C.A. Niemi (Ball State U.), I. Okonkwo (Purdue), R.J. Olsen (Wabash C.), C.M. Rogers (Indiana U.), J.C. Schumm (Purdue U.), E.M. Shull (N. Manchester), L.M. Baker (East Noble H.S.), T. Barker (East Noble H.S.), M. Booty (John Adams H.S.), T. Couillard (Highland Senior H.S.), J. Goldmann (The GAGE Institute), B. Killeen (John Adams H.S.), M. Kudrak (Northwestern H.S.), D. Lannuier (John Adams H.S.), D.J. O'Connor (East Noble H.S.), M.D. Owens (Marquette H.S.), and K. Ramos (Donald G. Gavit H.S.), and W.L. Kovach (Indiana U.).

Grants Received: Kappa Kappa Kappa Sorority made $2,500 available for awards and expenses for the Science Talent Search for Indiana high school students.

The American Association for the Advancement of Science granted $1,000 to be used by high school students for research.

VII. BUDGET FOR 1984

The following budget was approved by the Budget Committee in the meeting of 10 December 1983.

Academy Accounts		
Anticipated Income		
Dues, Initiation and Reinstatement Fees		
(30 @ $25, 570 @ $10, 280 @ $5, 75 @ $2, $100 @ $0)	$ 8,000.00	
Interest on Savings	2,000.00	
Reprint Charges to Authors: Vol 92 & 93	3,250.00	
Registration Fees	1,500.00	
Junior Academy of Science		
(Transfer from administered account)	434.58	
Centennial expenses (from reserves)	3,200.00	
TOTAL	$18,384.58	$18,384.58
Budgeted Expenditures		
Secretary	$ 600.00	
Treasurer	750.00	
General Office	250.00	
Officer Honoraria	150.00	
Membership Committee	800.00	
President's Contingency Fund	1,000.00	
Newsletter	900.00	
Speaker of the Year	700.00	
Program Committee	2,000.00	
Centennial Committee	2,600.00	
Editor's Expenses	700.00	
Youth Activities Committee	1,650.00	
Junior Academy of Science	1,000.00	
Biological Survey Committee	1,000.00	
AAAS Representative	300.00	
Section Chairmen's Expenses	50.00	
Public Relations	150.00	
CPA Fees for Tax Returns	500.00	
Finance Committee	450.00	
Miscellaneous	100.00	
Reprint Charges to Academy	2,850.00	
Transfers to Administered Accounts	$ 2,275.00	
Science Talent Search ($0.00)		
Research Grants ($0.00)		
Science and Society ($0.00)		
Natural Areas ($0.00)		
Library Binding ($1,500.00)		
Publications ($0.00)		
Proceedings: Mailing ($775.00)		
Registration Fees ($0.00)		
TOTAL	$20,775.00	$20,775.00
Budgetary Deficit		$-2,390.42
Endowment Funds		
Anticipated Income		
IAS Foundation (00430-00-0)		$ 2,000.00
J. S. Wright Fund (0043-01-9)		35,000.00
Invested Income Account (0043-02-8)		104,800.00
		$141,800.00
Budgeted Expenditures		
Bank Fee		$ 3,500.00
Research Grants for Senior Academy Members		22,500.00
Research Fellowships for Secondary School Teachers		3,000.00
Publications		
Proceedings - Volume 92 ($14,100 - 8,400)		5,700.00
History of the Academy		15,000.00
Other Centennial Publications		2,500.00
Award for Research Paper		300.00
		$ 52,500.00

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Restricted Accounts (accounted for elsewhere)	
Anticipated Income	
AAAS Funds for High School Research Grants	$ 1,000.00
Tri-Kappa Funds for Science Talent Search	2,500.00
Registration Fees	1,500.00
Sale of Publications	1,000.00
Income from Foundation Account	300.00
	$ 6,300.00
Anticipated Expenditures	
Research Grants Comittee - Junior Academy Grants	$ 1,000.00
Science Talent Search	2,500.00
Meeting Expenses	
Publications	300.00
Award for Outstanding Paper (Funds from Foundation Account)	300.00
	$ 4,100.00

Respectfully submitted,

Duvall A. Jones, Treasurer

We, the undersigned, have audited the Treasurer's records for the Indiana Academy of Science for the year 1983 and have found them to be accurate and in order.

Andrew G. Mehall

19 January, 1984

John Ricketts

1/24/84

INDIANA JUNIOR ACADEMY OF SCIENCE

The Indiana Junior Academy of Science has been more active this year, involving more students and a greater number of schools by virtue of having both a Spring and a Fall meeting. As reported previously, the first Spring meeting was held at Brown County High School in Nashville on April 30. The theme was caves. The 1984 Spring meeting will be hosted by Gavit Jr.-Sr. High School at Hamond. The ecology of the dunes will be the theme.

The Junior Academy is proud to announce that Keith Hunning's special desire for the Academy to send a delegate to the American Junior Academy of Science symposium has been accomplished. Jim Barsic, with his sponsoring teacher, Dean Christakis, attended the AJAS symposium at Detroit in May. Part of the afternoon program tomorrow will be a slide-illustrated account of Jim's experiences for the four days. An amount of six hundred dollars ($600) was allocated for this activity. The Junior Academy remains within its budget. It is proposed that this activity continue as a special incentive for students and teachers.

Some changes in format have been made for the Fall meeting. The Mouse Trap Car and Paper Plane contest have been eliminated so that there is no competing activity going on during the paper presentations. In a mailing, teachers were asked to urge their students to attend the presentations as a learning experience.

Due to intense competition developing between two schools, the large trophy for Best Over-all School has been eliminated. This also is a monetary saving.

The practice of awarding a year's membership in the AAAS to The Outstanding Junior Scientist-Senior Division has been reactivated. This includes a subscription to *Science 83*.

The subject of a registration fee has been discussed by the Junior Academy Council. In general, the Council is in favor. This will be acted upon after the Senior Academy has made its decision.

Necrology
Fay Kenoyer Daily, Butler University

EBERHARD FRIEDRICH FERDINAND HOPF

Salzburg, Austria — Bloomington, Indiana
April 17, 1902 — July 24, 1983

A renowned mathematician, Dr. Eberhard Hopf, was a native of Salzburg, Austria. Born April 17, 1902, he spent his first 28 years in Europe. He was educated at a secondary school in Berlin-Friedenau from which he graduated in 1920. A Ph.D. degree was earned from the University of Berlin in 1925 and Habilitation in 1929. He was an instructor there from 1929 to 1930.

Dr. Hopf came to America as an International Fellow at the Rockefeller Foundation where he taught from 1930 to 1932. Then, he went to the Massachusetts Institute of Technology from 1932 to 1936. He was back in Europe as Professor of Mathematics at the University of Leipzig from 1936 to 1944 and Professor of Mathematics at the University of Munich from 1944 to 1948.

Dr. Hopf moved to Indiana University, Bloomington, Indiana, September 1, 1948, serving as Professor of Mathematics until 1962. From 1962 to 1972, he was Research Professor of Mathematics becoming Research Professor Emeritus of Mathematics July 1, 1972.

Dr. Hopf was one of the prominent figures in 20th century mathematics. His colleague at Indiana University, William Ziemer, said that "Many of his mathematical discoveries are now basic principles . . .". He contributed many articles to mathematical journals and wrote *Mathematical Problems of Radiative Equilibrium* (Cambridge University Press, 1934) and *Ergodentheorie* (Berlin, Springer. 1937).

Dr. Hopf was not only recognized for his eminent research reputation, but when he was named Research Professor of Mathematics at Indiana University, he was congratulated on his contributions "to a better academic life at the university".

His chief research interests were: differential equations, integral equations, calculus of variations, mathematical astronomy, theory of measure and probability, ergodic theory, celestial mechanics, and turbulent fluid flow. His work brought recognition from the American Mathematical Society in 1981 when he was awarded the Steele Prize "for a paper . . . proved to be of fundamental or lasting importance in its field, or a model of important research." According to an Indiana University News Release (June 2, 1981) the award was actually for three papers. Dr. Hopf contributed a method of solving equations applied to problems of fluid mechanics, solid mechanics and chemical reactor theory. Another paper analyzed turbulence in a viscous fluid inspiring further work in the field. The third paper analyzed an important equation in fluid dynamics laying the foundation for a method now used to deal with equations describing shocks.

Frequently, Dr. Hopf was invited by universities and scientific organizations to give lectures. He visited the University of Heidelburg, Gottingen, Mainz, Tuebingen and Munich in 1954. He lectured at a mathematical conference on ergodic theory in California, 1955. He was Visiting Professor of the Mathematics Research Center at the University of Wisconsin from February to August, 1959. He was invited to take part in international invitational conferences in Varenna, Italy, in 1960.

Dr. Hopf joined the Indiana Academy of Science in 1951 and gave a paper that year on *A mathematical problem in hydrodynamics*. He served as Section Chairman of

the Mathematics Section in 1952. In 1953, he gave another paper on *Quadratic forms in vector spaces*. Other societies to which he belonged were: German Mathematical Society, American Mathematical Society, Saxon Academy of Science, Bavarian Academy of Science, and Sigma Xi. He was co-editor of mathematical monographs and a mathematical journal. Biographic sketches of Dr. Hopf can be found in *Who's Who in Indiana* (p. 107), *Who's Who in the Midwest* and *American Men and Women of Science* (1982), 15th edition. We are grateful to Indiana University for providing much archival material.

After suffering a long illness, Dr. Eberhard Hopf died July 24, 1983, in the health center of the Meadowood Retirement Community at Bloomington, Indiana, where he lived. He had achieved a very fruitful, distinguished career during his 81 years of life.

RODERIC MALCOLM KOCH

Evansville, Indiana
September 29, 1904

Evansville, Indiana
November 12, 1981

Mr. Roderic Malcolm Koch was an Evansville manufacturing executive with many facets to his interests. He was born in Evansville, Indiana, September 29, 1904. His early education was obtained from the Centennial Grade School and Central High School of Evansville. He attended the University of Wisconsin from 1922 to 1923, and received an A.B. degree from Evansville College in 1945. He received an honorary degree from Indiana State University-Evansville in 1980 for his many contributions to the cultural life in Evansville.

Mr. R.M. Koch was the grandson of George Koch who founded George Koch and Sons, Incorporated, in 1873 in Evansville. Roderic joined the firm as machine shop foreman in 1924 which position he held until 1930. He was then assistant shop superintendent from 1930 to 1934, superintendent from 1934 to 1938, assistant general manager from 1938 to 1941, general manager from 1941 to 1951, vice president from 1951 to 1955, executive vice president from 1955 on. He also was president of the Standard Industrial Products Incorporated, Evansville; Koch Industrial Equipment, Incorporated; McMasters Incorporated Plastic Manufacturers; R. Malcolm and Associates advertising agency. He was vice president of Kaysons Incorporated; Modern Products, Incorporated; on the Board of Directors of Santa Claus Samaritans, Santa Claus, Indiana; treasurer of the Evansville Public Schools from 1943 to 1946; president and director of the Astronomy Section of the Evansville Public Museum, president of the Indiana Foundation for Arts and Sciences, 1966.

Mr. Koch was a philanthropist who had an interest and curiosity about many things. He was instrumental in the founding of the Evansville Museum which was built entirely with public donations. The planetarium was named for him, and he championed the cause of science there which was one of the main reasons for the expansion in that area. The first R. Malcolm Koch lecture which was on space exploration was given just before his death. He also donated paintings to the museum and was interested in coin collecting.

Mr. Koch found time to devote to the Salvation Army by serving on the Board. He received the "Others Awards" from them in 1980 for his work with the Army and the museum, the first time a board member had ever received the award.

Santa Claus Land, Incorporated, was also a family operated business. According to his brother, Mr. R.M. Koch was instrumental in establishing Holiday Village at Santa Claus Land and was active in serving on the board.

Mr. Koch joined the Indiana Academy of Science in 1949 listing Chemistry and Geology and Geography as his chief interests. He was a member and director of the Evansville Manufacturers and Employers Association, Evansville University Presidents Club and Alumni Association vice president (1966), Evansville Astronomical Society, Conrad Baker Foundation, Deaconess Hospital Foundation, Wessleman Park Nature Center, Indiana State University-Evansville Century Club and a member of the advisory board of the Evansville Foreman's Club. For biographic data see *Who's Who in the Midwest*. Mildred I. Harmes of George Koch Sons, Incorporated, a former assistant to Mr. Koch, kindly provided an obituary prepared for press release and a reprint from the Evansville Press.

Mr. Koch was still working for the air conditioning and industrial equipment company founded by his grandfather when he was stricken at work. He died later at the Deaconess Hospital in Evansville, November 12, 1981. He was highly regarded in his community. In a fine article about him on the front page of the *Evansville Press* (Nov.

13, 1981) it was stated "If Evansville could have but a few dozen more R. Malcolm Kochs, there would be ample reason for optimism about our community's future."

BASIL ELWOOD MONTGOMERY

Near Cynthiana, Indiana
October 10, 1899

Lafayette, Indiana
January 19, 1983

Dr. B. E. Montgomery was born in Gibson County along the Posey County line near Cythiana, Indiana, October 10, 1899. He attended the Cythiana grade school and graduated from the Poseyville High School in 1918.

His teaching career began in 1918 in a one room schoolhouse where he taught all eight grades. He taught public schools until 1928 during which time he was a teacher of Science, History and Latin. He was also a teacher and principal of schools in Posey (1918-1921); Pennville, Wayne (1922-1924); Monroe, Adams (1925-1926); Owensville, Gibson (1926-1927); and Evansville, Vanderburg (1927-1928) Counties in Indiana. His higher education was interspersed between his winter teaching schedule earning a B.Sc. degree from Oakland City College in 1922. He taught History and Mathematics there from 1920 to 1922. In 1925, he obtained an M.S. degree at Purdue University majoring in Entomology and Education. He was also a teaching assistant in Biology there. He studied Parasitology at Iowa State University (Iowa City) during the summer of 1927, and was a graduate assistant in Entomology and Zoology at Iowa State University (Ames) from 1928 to 1929.

In 1929, he came back to Purdue University as an Instructor of Entomology where they needed someone with a knowledge of beekeeping. He was hired because of his long time interest and expertise with bees which began in childhood when he learned beekeeping methods from his father. Related research was one of his chief interests professionally.

In 1936, he received a Ph.D. degree from Iowa State University.

During World War II between 1939 and 1943, he also taught Mathematics at Purdue University.

Dr. Montgomery was married in 1930 to Esther Barrett and they raised a daughter, Emily. Both Mrs. Montgomery and Emily played an important part in Dr. Montgomery's career and he named dragonflies for them. His interest in dragonflies was influenced by Dr. E. B. Williamson, president of the Indiana Academy of Science in 1918, with whom Dr. Montgomery became well acquainted when teaching in Adams County. It was about twelve miles from Monroe, where Dr. Montgomery was teaching, to Bluffton where Dr. Williamson was a banker and lived. Dr. Montgomery spent many nights studying notes and manuscripts loaned by Dr. Williamson. After Dr. Williamson died in 1933, Dr. Montgomery carried on much of Dr. Williamson's work.

During the 1900s, scientists were not able to specialize in the subjects taught to any great extent. Consequently, Dr. Montgomery taught a variety including General Entomology, Aquatic Entomology, History of Entomology, Morphology, Physiology, Entomological Tehcniques, Literature of Entomology, Beekeeping, Biology and Life History of Insects, Economic Entomology, Systematics and Taxonomy.

His work became well known internationally and a number of research grants, honors and responsibilities came his way.

He was with the Entomology Laboratories of the U.S. Department of Agriculture in New Jersey, Louisiana, Indiana and Ohio during the summers from 1922-1948. He then received Fulbright grants in 1949 and 1950 to specialize in bumblebees and cloverseed production at the Cawthorn Institute, Nelsen, New Zealand. In the summers of 1955 and 1956, he was at Point Barrow, Alaska, as a Research Biologist with the Office of Naval Research, Arctic Institute of North America to study the ecology of bees.

In 1942, a Sigma Xi grant was received by him to study dragonflies at the Museum of Comparative Zoology at Cambridge, Massachusetts. In 1960, 1964, 1965 and 1968, National Science Foundation Grants were given to him to study specimens in European museums. He received the D.Sc. Honoris Causa from Oakland City College in 1978.

In addition to his studies on distribution, seasonality and classification of insects, he studied the relation of climatic factors, chiefly photoperiod and temperature, upon plant production and growth rate of insects. The development of special strains of legumes and bee handling techniques were sought to improve agricultural production. Dr. Montgomery developed a method whereby legumes and other crops may be pollinated by bees in cages in order to study them. He also developed a strain of clover which produces two seeds in a pod instead of one. He studied climatic factors and photoperiod impact upon the biology and life history of dragonflies during 1960 and 1968 under the auspices of Purdue University Experiment Station. He produced more than 100 journal articles. A bibliography of papers is given in a fine biographic sketch of him in 1974 by J.M. Macklin entitled *To B. Elwood Montgomery on his 75th birthday* published in *Odonatologica* (III (4):203-209) from which much information in this report was derived. (Dr. Montgomery, aware that his days were numberd, kindly supplied us with a copy. His thoughtfulness was manifest in many things that he did.) Dr. Montgomery owned one of the largest collections of dragonflies. He listed the dragonflies of North America and compiled a bibliography of all papers written about them. For a while, Dr. Montgomery initiated and edited *Selysia*, a newsletter on Odonatology. He also edited the *Colloquium on Odonata*, 1963, which was a report from the first worldwide colloquium on Odonata organized by Dr. Montgomery and held at Purdue University in 1963.

He did much to popularize science and gave many public lectures using live bees to illustrate the talks. One year, early in his career, he gave 48 lectures in a four-month period to a wide audience of pre-school students as well as retired people. He wrote *Bumblebees and bombiculture* for *Outdoor Indiana* (June, 1961). A short biography of the author accompanied that.

Dr. Montgomery became Professor Emeritus in Entomology at Purdue University June 30, 1968. He then taught at Marian College (1969) in Indianapolis and Frostburg State College (1969-1972) in Maryland.

One of Dr. Montgomery's hobbies was photography which was used often for illuminating illustrated lectures.

Other biographies of Dr. Montgomery can be found in *Who's Who in Indiana* (p. 154), and *Indiana Scientists* by S.S. Visher. His work was often the subject of Indianapolis newspaper articles. He was the subject of an article in the *Indianapolis Star Magazine*, November 17, 1957. He also wrote to Walter Cory to share with us some recollections and activities in the Academy. These were published in the *Newsletter* 36, April, 1982. Dr. Montgomery joined the Indiana Academy of Science in 1922 and was quite active. He was a member just over 60 years. He was elected to Fellow in 1929 over 50 years ago. He served on two committees in 1927-Program and Archeological Survey. From that year forward, he missed very few years in which he was not serving in some capacity. He was on the Biological Survey, Program (twice), Resolutions and Fellows committees and was often chairman and thus on the Exeuctive Committee also. He was Chairman of the History of Science Section in 1955 and of the Entomology Section in 1962 and 1963. He was again Chairman of the History of Science Section in 1969.

Dr. Montogmery gave about 45 papers before Academy Sessions. Many of these were in his series on Indiana dragonflies. He related the history, *A century of Odonatology in Indiana* before the History of Science Section in 1944. Many of his

other papers touched on subjects relating to bees, history of Entomology, etc. Dr. Montgomery addressed the Academy at the spring meeting of 1976 on the *Life and times of Thomas Say* (Proc. I.A.S. 86: 228-229. 1977. Abstract based on address). It was the National Bicentennial and Sesquicentennial of Science in Indiana and also the sesquicentennial of the year Thomas Say and other scientists came to the Owen community at New Harmony, Indiana.

Dr. Montgomery died in Lafayette on January 19, 1983, after a lingering battle with cancer. His career had not only led to important scientific discoveries but also captured the popular fancy. He was an energetic man, kind friend and staunch supporter of the Academy.

HERMAN GEORGE WILHELM, JR.

Somerset, Pennsylvania — Kokomo, Indiana
October 18, 1920 — August 10, 1982

Somerset, Pennsylvania, was the birthplace of Mr. H. G. Wilhelm, geneticist and microbiologist. He was born October 18, 1920, and was raised in the mountains of western Pennsylvania.

He was a graduate of the University of Pittsburgh receiving a B.S. degree in 1941 and an M.S. degree in 1947. His major subjects were genetics, microbiology, anatomy and physiology. He became a lieutenant in the United States Navy and served from 1942 to 1946 during World War II. He was executive officer and navigator for the USS Platte. From 1947 to 1951, he was an Instructor in Biology at the University of Dayton, Dayton, Ohio. He was assistant professor at Morris Harvey College from 1951 to 1955 when he returned to the University of Pittsburgh to work on a doctorate in microbiology. Due to a growing family and attendant financial difficulties, he could not complete his degree. He taught at St. Joseph School of Nursing as well as various other schools of nursing in the Pittsburgh area. He also served the Department of Health, Allegheny County, Pennsylvania.

Mr. Wilhelm came to Indiana in 1962 to teach at Franklin College, Franklin, Indiana, where he stayed until 1966. He then moved to the Indiana University campus at Bloomington, Indiana for a year, and then on to Kokomo, Indiana where he taught at Indiana University at Kokomo.

Mr. Wilhelm was a very dedicated and effective teacher. In a memorial resolution by Ruth Hanig, Gary Dolph and Steven R. Johnson (kindly provided by Indiana University at Kokomo) some students' quotes were included such as: "He brought microbiology down to earth" and "We really learned microbiology." He made a great effort to assist students in the laboratory and present material relevant to special courses of study for nurses and other scientific endeavors that the students might be pursuing. Mr. Wilhelm was especially interested in human genetics and genetic engineering. He also was interested in environmental matters.

Mr. Wilhelm was a member of the Indiana Academy of Science only a short time joining in 1979 as a senior member. Bacteriology was listed as his major interest. He was also a member of the A.A.A.S. and fraternal groups of Masons, Shrine, and Scottish Rite. He was an adviser for the DeMolay and on the board of directors for the Howard County Red Cross. He is listed in *American Men of Science* (9th ed.) 1955, Physics and Biology Section.

Mr. Herman George Wilhelm, Jr. was very ill in December 1981 developing a collapsed lung and spending New Year's Day in an intensive care ward. He recovered enough to return to teaching in March, 1982, carrying a full teaching load during the second summer session with an arranged course in Genetics extra. He was very ill the last few weeks of the session and had just prepared his final grades before he died. He was at home listening to a selection from his large collection of violin music when he died August 10, 1982. The memorial resolution by his colleagues demonstrates the high regard and affection with which he was held by both student and faculty at Indiana University at Kokomo.

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ADDRESS AND CONTRIBUTED PAPERS

TECHNOLOGIZING SCIENCE

Alice S. Bennett

I am pleased to have the honor to address the members of the Indiana Academy of Science at a time when we are looking forward to celebrating our centennial year. The Indiana Academy of Science has functioned effectively for almost one hundred years as an organization whose principal objectives are to promote scientific research and the diffusion of scientific information; to encourage communication and cooperation among scientists . . . and to improve education in the sciences'' (1). I believe that the members of this Academy will continue to assume important leadership roles in promoting science in the state of Indiana during the coming year and the following hundred years. I also believe that if we are to assume leadership during this period of the computer revolution, the crisis in science and mathematics education, and the loss of international superiority in advances in science and technology, we, ourselves, must clearly understand the nature of science. We must understand the definition of science. This is not an exercise in semantics because the way we define science has a profound impact on how we do science.

It is not the intent of this presentation to make value judgments as to the relative importance of either science or technology. Technology is dependent on the findings of science and the furthering of scientific investigations is dependent on the tools created through technology. However, I would contend that it is imperative that we, as scientists, understand the meaning of science and distinguish between 'research and development' and 'science and technology' and place each in its rightful position of priority, if we are going to be able to define the relationship of science to society, and to face the challenges of the 1980s.

Tonight, as we are looking forward, I would like to take a brief look backward as well, in an effort to put the present into some perspective. The advancement of science during the last hundred years has been fast and overwhelming. A look at the ''100 years ago'' section of recent issues of Scientific American reminds us that at the time the Indiana Academy of Science was chartered the existence of sub-atomic particles was unknown, chromosomes were unknown, enzymes, nature's catalysts, were still a mystery, and radioactivity had not yet been discovered. Indeed, it was only about 50 years ago that the first protein was isolated and shown to have enzymatic activity, and that the quantum atom was described.

The accomplishments of science and technology during the last three decades have been increasing logarithmically and are too numerous to even begin to list. The explosion in science and technology in the past decade has been, at best, unbelievable. This explosion is not only pushing forward the frontiers of knowledge, it is also affecting the lives of citizens in a way that is without precedent, and has created an upsurge of interest in science, science education, and technology. How to deal with this revolution will be a prime concern during the first years of our second hundred years.

The upsurge of interest in science, technology, and science education is not new. Many of us can remember the reaction of the country to the launching of Sputnik by the Russians. I remember October 4, 1957 very well, but it had a different significance

for me since that was the day our first son was born. Some years later he was quite impressed to realize that he was born at the beginning of the space age. At that time the response of the country and the scientific community was to support new approaches to science education, to increase the budget for scientific research, and to expand our technological and space efforts. These actions gave birth to the golden age of science. Researchers had almost unlimited freedom to pursue studies which were truly basic science. It was largely upon this foundation that the rapid advances in applied science and technology in the 70s and 80s were based. However, by the early 1970s science was under severe attack. This led to calls for a moratorium on science and the now-famous "Golden Fleece Awards" which went to any research that did not show immediate results.

A number of writers have suggested that the anti-science attitude of this period was really a dissillusionment with the apparent failure of technology to solve all of our problems and the realization that technology actually created many expensive

At the dinner meeting Alice S. Bennett delivers her Presidential Address, "Technologizing Science."

problems. This represents an obvious confusion of technology and science. Now, 10 years later the interest in science and technology has been rekindled. We hear that it is an important, indeed, a prime objective of the nation and the state of Indiana to develop a scientifically literate population and to educate young scientists. As a scientist it is gratifying to see this rekindled interest in science, technology and science education, but it also causes me to have some grave concerns. At this time I would like to share some of these concerns with you.

In discussing these concerns I will:

1. Discuss the factors that contribute to the misuse of the of the term science.
2. Expand on what is meant by the terms science, technology, basic research, and development.
3. Consider the implications of confusing technology with science.
4. Suggest some approaches for scientists to use in the coming years that may prove to be productive.

How are the current problems in dealing with science and technology different from those encountered in the past? I believe there are factors that make it difficult for us to act objectively. *First*, the development of computer technology has produced some of the most rapid changes in society that have ever before been seen. In addition, the advent of this new tool has been confusing and, indeed, frightening for many laymen and scientists. I believe that many are at a loss as to how to cope with the problems and solutions to problems created by this powerful capability. I'm sure many persons view computer cabability equivalent to Big Brother in Orwell's 1984 (2). They forget that we, not the computer, are in control. *Second*, there are the economic factors. A depressed economy does not lend itself to considerations of well planned short-term or long-term solutions to problems. *Third*, there is a change in policy and level of government support of research and science education. Along with this change there is an increased reliance upon private industry to fund research. This shift in funding and change in emphasis is coming at a time when there is an out-cry for the development of a scientifically literate population as well as for jobs for the unemployed.

A key question is, "Are we, as a group of scientists providing the type of leadership that is necessary for the growth of science and for the development of a scientifically literate population? Do our actions really reflect our concern for science education? Are we, along with society, in our overzealousness to attack the immediate problems of today, confusing what is meant by science as compared to technology; research compared to development. Are we using a form of 'Newspeak', as described in Orwell's 1984 (2), where 'Technology is science' and 'development is research'? Are we technologizing science?"

Let me give you some examples. A popular magazine (3) counsels young people considering careers, "The key question you have to ask yourself is, 'Will there be a strong demand for my particular expertise in the future, . . .?'. The all-important given is—-you guessed it—-technology." Actually the 1980 forecasts by the Bureau of Labor Statistics predict that high-technology occupations, as a group, will account for only 7% of all new jobs between 1980 and 1990 (4). In last Sunday's Family Weekly magazine (5) the caption for the lead article read "Futureworld: How Will Science Change the Way You Live". The article actually deals with technological advances such as robotics, talking toasters and applications of computers to psychiatry. The word, science, is not used in the article.

R. Van Norman, in the textbook *Experimental Biology* says,

"The public impression of the goal of science seems to be approximately the following: Science is working hard (1) to find ways of raising enough food to feed all the people, (2) to improve medicine so that the people can stay alive to eat the food, and then (3) to develop more terrible weapons to wipe out this larger, healthier population. These and other technological aspects of science make good news stories, even though they give a distorted picture of science."

The following are quotes from persons who are responsible for guiding the course of science in the nation, including the Presidential science advisor. "Then there is the whole question of accountability in basic research. Is basic research contributing to society in ways Congress and the public expect it to be? Has it fulfilled the endless frontier spirit?" (7). "I think we've shown this year that government will respond enthusiastically when it's presented with programs, **even as esoteric as basic research**, with clear relevance and importance to national objectives. (emphasis mine) (8)." ". . . while researchers may pursue basic knowledge it should be attuned to the opportunities of the industrial world." (9). A secondary school teacher confided in me that she was not allowed to buy supplementary teaching materials for her classes because most of the budget was now going to computers. There is obviously confusion about what science, basic research and technology really are.

There is a tendency to look for immediate solutions to problems that have been in the making for a long time and to jump on band-wagons. I believe that calling support for technology support for science can be misleading and costly and will not lead to solutions to the problems of society and improving the scientific literacy of our people.

The primary aim of science is not application, it is gaining insights into the causes and laws which govern natural processes. This is not to say that science must be conducted, or ever is conducted in a vacuum. In 1972, Victor Weisskop, a member of the National Academy of Sciences, said, "I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsence it has been my fortune to stumble upon." (10) H.B.G. Casimir, commenting at the Symposium on Technology and World Trade in 1966, gave the followings as examples of how decisive technological progress was made by scientists who did not work at all for a well-defined practical aim are:

1. Basic circuits in computers were not found by people who wanted to build computers, but instead were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.

2. The nucleus of the atom was not discovered by people who wanted a new power source, but by the Curies and Rutherford and Fermi and a few others.

3. Electrons were not discovered by people in search of a different light source, but by people like Thomson and Lorentz.

4. The discovery of electromagnetic waves was not the outgrowth of of an urge to provide better communication, but by Hertz who emphasized the beauty of physics and who based his work on the theoretical consideration of Maxwell (11).

Weisskopf concludes that there is hardly any example of twentieth century innovation which is not indebted to basic scientific thought. In searching for new insights the scientist is often forced to extend the technological frontier.

In a letter to the editors of Chemical and Engineering News, Paul Lindenmeyer, President of Dynamic Materials, Inc. says, "It is surprising how few people are able to distinguish clearly between science and technology, between research and development. . . . so few people realize that the second item is impossible to achieve without

a sufficient amount of the first. It is not possible to achieve new technology without sufficient knowledge of the underlying science or to have a successful development without the required results of research." (12) He further points out that commercial companies will spend millions to develop marginally improved technologies, but refuse to spend money for research. He suggests that one must distinguish between science and technology and research and development and that the first is not only essential to the second, but also can be accomplished for only a fraction of the cost of the latter.

What are the implications of saying technology when we mean science—what are the problems with technologizing science? *First*, defining expected outcomes of basic research and science encourages what is fashionable at the expense of off-beat work that might be truly creative. In a recent seminar, a noted researcher stated, "Writing some parts of research proposals have become a little like writing science fiction." At the present time it would have been difficult, if not impossible for Dr. McClintock to have done the work which led to receiving this year's Nobel prize in medicine. Now, the emphasis on immediate results far out-weighs the traditional search for scientific truth. The emphasis on publication as a necessary criterion for advancement discourages long term thoughtful research. I was sorry to hear a scientist state, "We must get another paper accepted for publication, so that we can get enough money to continue our research." That is not the reason for publishing scientific papers. I recognize that this problem of publishing has always existed but in today's scientific climate, its effect has been magnified. Equating immediate results with the ability to continue scientific research is counter-productive. I would not suggest that results are not important. I am more concerned with the timing.

This leads to the real concern that opportunities to increase the scientific base are diminishing. Ten years ago Weisskopf said, "One could conclude that tasks are for applied science only and that research . . . not directed toward one of the specific problems is not necessary. It may be harmful since it takes away talented manpower and resources. This is not so. The spirit of basic research is . . . to find connections and dependencies, causes and effects, laws and principles. This attitude of basic research is necessary for the solution of today's pressing problems because it leads people to search for causes and effects in a systematic way, regardless of any ulterior aim." (10) These words, I believe, are even more relevant today than they were ten years ago.

Second, an emphasis on results leads to a disproportionate concern for protecting those results. Whatever can possibly be patented is being patented. Doctoral students are being counseled to patent their doctoral dissertations whether they contain marketable material or not. Graduate theses, written by students supported by industry, are not publishable until they are released by those corporations. Some of the cooperative efforts between universities and industry have been successful, but much of the resultant research has been directed toward the achievement of immediate results and are not being shared with the rest of the scientific world. Free communication of scientific knowledge is also being restricted by the present administration. Frank Press, the president of the National Academy of Sciences, has warned, "standards and laws preventing open communication would be counterproductive and harmful."

Editors of the Christian Science Monitor commented ". . . the United States must maintain a strong foundation of fundamental scientific and engineering research if it is to compete in today's world . . . but this foundation which depends on free communication and on support for widespread creativity, cannot be maintained if basic science is to be fettered by constraints that are more appropriate for the development of weapons or of proprietary products 'attuned to the opportunities of the industrial world'." (9)

Third, the crisis in science and mathematics education cannot be solved by simply buying more computers for more schools that have teachers who are unprepared for using them effectively in teaching science and mathematics. The public truly believes that we are making inroads into solving our problems in scientific literacy by buying more computers. I believe it is unfortunate that the term computer science has come to be used so indiscriminately. There is a science which should be called computer science, but too often the term is used to refer to the use of computer languages, word processing, and game-playing. We, as scientists need to gain expertise in using computers to further our science and to teach science more effectively. We cannot, however, allow society to confuse buying more computers with funding science education.

In writing about "Science and the Atari Generation", Sheila Widnall, Massachusetts Institute of Technology, asks, "Is it necessary to be an electrical engineering or computer science major to participate in the computer revolution?" (13). She concluded that most students must believe so. From 1973 to 1983, the course preference of new undergraduates for physics declined from 19 to 8 percent, for mathematics from 18 to 6 percent and for chemistry from 8 to 2 percent, while engineering majors increased from 38 to 75 percent. In addition, she notes that the students who do not choose science are the best.

Fourth, funding for both science and technology is important if we are to deal with the problems of the future; but let's be clear about what we are funding. It is of interest to look at the federal budget for research and development for the last ten years (14). In constant dollars, federal funding for basic research was 2.6 billion dollars in fiscal year 1967 compared to an estimated 2.8 billion dollars in fiscal year 1983, 2.5 billion in 1982 and 2.4 billion in 1981. Funds for applied research have also remained at a relatively constant level. The dollar amounts are similar but this is illusory when one considers that the rules of the game have changed. The administration is targeting its support to fields where it can foresee some immediate payoff. Are we encouraging what is currently fashionable at the expense of truly creative work? When we confuse what is meant by science and by technology, we do not notice that actual support for science is diminishing.

In conclusion, I believe that, as members of the scientific community and as members of the Indiana Academy of Science, we have an obligation to work toward the stated objectives of this organization. If we are to do so, we must understand clearly what we are about and communicate the meaning of science to students, the public and policy makers. We are fortunate in having a framework for this task already in place. Through our various committees we have the mechanisms for interpreting science to the people of our state, providing scientific input into the functioning of state agencies, and providing leadership in the policy-making processes. By maintaining close relationships with the Junior Academy of Science we can serve as models for junior and senior high school students who can observe scientists in action and communicate directly with them. Through our research grants programs we are able to encourage and support quality research projects of senior scientists. Each year talented high school students are also benefiting from these programs. Many of these young people are presenting results of their studies at state and national science meetings and Science Fairs. How better to learn the meaning of research than to do it yourself? It is in these activites that we have the best opportunity to have an impact on the future scientists of our state. It is here that we are able to convey to them the meaning of the scientific process and separate science from technology. By expanding our newly founded Fellowship for Secondary Science Teachers program we will be able to help more teachers understand more clearly the research process so they can provide research opportunities for their students and teach the true the meaning of science. Through

these and other programs of the Academy we will hope to have a positive impact on science in the state. What we do in the state of Indiana is only a small part of a larger effort, but none the less an important one.

As individual scientists we also can promote good science. I believe we have an obligation to help establish guidelines for funding research, both from the public and private sector. We must provide this leadership and not leave it to those who are less informed about the meaning of science. We need to be aware of the rules of the game we are playing when those of us in the academic community enter joint ventures with governmental agencies and private industry. We must ask these questions: "What are the restrictions in the project?" "Am I simply working part-time for that organization, providing data for projects they designed?" "Will I be able to freely communicate my findings with other scientists?" "Is this project detracting from my established research interests?" These questions should be answered within the framework of a clear understanding of the meaning of science and research.

Science contains many activities, most of which can be achieved more efficiently with the use of mordern technology. Out of this science will emerge the basis for future technology. However, this cannot be the sole purpose of science. Science cannot develop unless it is pursued for the purpose of pure knowledge and insight. If we 'technologize science' we will not only stand in the way of scientific development, we will also obstruct the development of technological advancements.

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During a luncheon break, several longtime members of the Academy discuss plans for the centennial year. Clockwise, beginning at left, are Robert H. Cooper, William A. Daily, Charles B. Heiser, Jr., Fay (Mrs. William) Kenoyer Daily, and Mrs. Robert H. Cooper.

DRUGS AND THE MIND

E. Campaigne*,
Professor Emeritus of Chemistry,
Indiana University, Bloomington, Indiana 47405

Introduction

For purposes of this discussion, the mind, or psychoses, is the thought processes involved in meeting the problems of life. These processes are fundamentally biochemical, and a good review of current knowledge about these biochemical processes has recently appeared (6). In this paper, I plan to review briefly the history of the discovery of psychopharmacological agents, wtih some discussion of drugs commonly used, which have some affects on the mind. A technical solution to a major societal problem may lead to new problems, and the history of this event can be used to illustrate how some useful drugs were discovered, and provides an opportunity to discuss the relationship of biological activity to molecular structure in certain compounds.

Recognition of the Problem

By 1950, it was recognized that admissions to mental hospitals in the United States was increasing at a rate of ten to twelve thousand per year and that if this rate continued, it was projected that every hospital bed in the United States would be occupied by a mental patient by the year 1970. These figures were useful in getting increased Federal funding for hospital construction. In 1950, treatment for mental disease was basically custodial care, which could be very expensive, as these patients were frequently destructive. Historically there were two different treatments developed for this disease, commonly felt to have supernatural overtones, and be the result of possession by evil spirits. The skulls of primitive men somethimes show that they had holes drilled in the forehead, to let out the evil spirits. In 1950, a patient might be treated by a surgical procedure, Frontal Lobotomy, in which a hole was drilled in the forehead, and the frontal part of the brain destroyed. Another treatment, used in the Middle Ages, involved lowering a mentally disturbed person into a pit of vipers, tied by the ankles, so that the head came near the dangerous animals. When properly done, the patient would go into shock, and on recovery seemed much improved. In 1950, electroshock or insulin shock therapy was frequently used, with similar results.

In 1955, the U.S. Public Health Service reported that 559,000 beds were occupied by mental patients, and they anticipated an increase of 12,000 by 1956. However, in 1956 the number of beds occupied by mental patients was down by 7000, and there has been a steady decrease since then despite a population increase. The use of electoshock therapy has been cut by 80-90% (2).

Psychopharmacological Agents

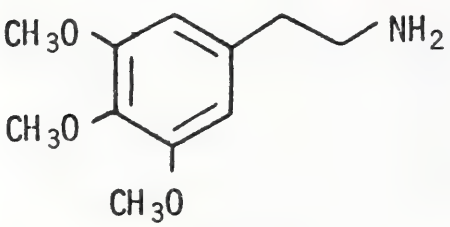
The reason for this sudden reversal of the trend in hospital bed occupancy by mental patients has been called the most significant development in chemotherapy since Penicillin. It was the discovery that mental disorders could be treated by chemcial substances, and that mental disease may be a metabolic disturbance, comparable to other metabolic disorders, such as diabetes. This represents a breakthrough in thinking about mental disease, as the general populace still, in the middle 1950s attributed some supernatural character to mentally disturbed patients. "He behaved like a man possessed", they would say. It is interesting that this breakthrough in thinking about

*Indiana Academy of Science "Speaker of the Year," 1983-84

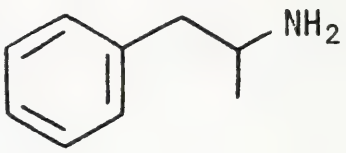
mental disease, i.e. that it might be treatable with chemicals, had not occurred earlier. Afterall, chemical agents affecting the psychoses had long been known and used for that purpose.

Hallucinogens

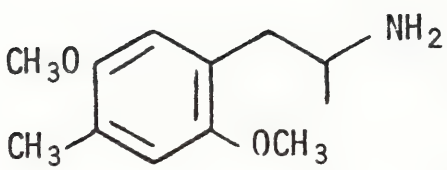
The early Greeks described the Eleusinian Mysteries, describing strange dreams by those who partook of potions in the city of Eleusis, The Hashishin, or assassins, were eaters of hashish, extracted from Cannabis Indica. The Norse Berserkers achieved the proper mental state for reckless attack by eating certain mushrooms, and certain



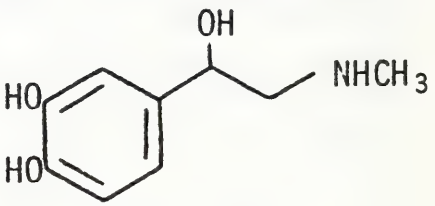
mescaline



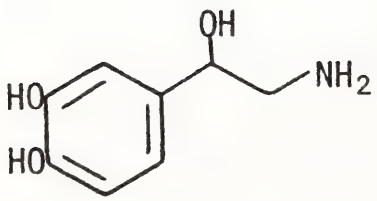
benzedrine
(amphetamine)



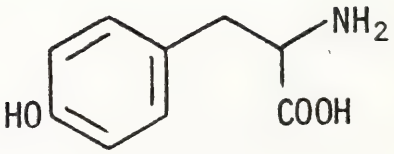
STP



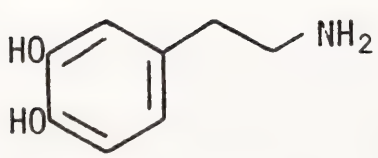
adrenaline
(epinephrine)



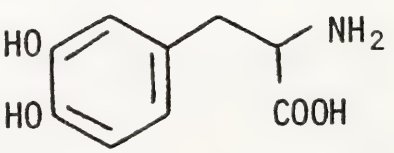
norepinephrine



tyrosine



dopamine



L-Dopa

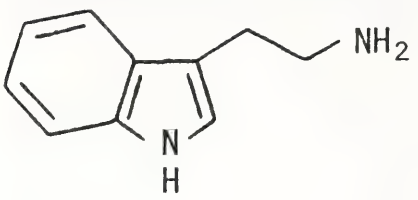
FIGURE 1.

voodoo cults used oloiuqui, an extract of Morning Glory, for religious hallucinations. These are all psychadelic drugs, and contain chemical agents which cause hallucinations and irrational behavior. In our own southwest, the Mescalero Indians have long used the mescal cactus to induce a religious mood in Native American church ceremonies. The mescal cactus contains mescaline (see Figure 1), the structure of which was established in 1900. The nature of the hallucinations caused by mescaline, "dreams in Technicolor", is beautifully described by Aldous Huxley in "The Doors of Perception" (5). Benzedrine, having an *alpha*-methyl group (see Figure 1) is about ten times as potent as mescaline as a psychomimetic agent, but the hallucinations are not the same. A synthetic substance called STP on the street (2,5-dimethoxy-4-methylphenylisopropylamine, see Figure 1) is about one hundred times as potent as mescaline in causing hallucinations, so that five to ten milligrams gives the effect. The drug benzedrine, or amphetamine, is commonly used as an appetite suppresant (anorexant) and central nervous system (CNS) stimulant. At low dosage (10 to 20 mg.) it serves to keep one awake. The danger is overdosage. Fifty to one-hundred milligrams can have serious psychomimetic effects, so it is about ten times mescaline in activity as a hallucinogen.

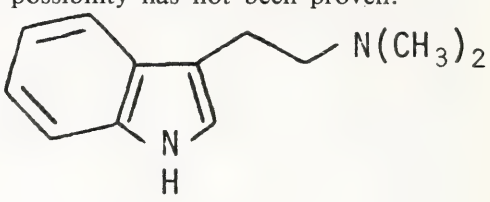
It is interesting to compare the molecular structure of these hallucinogens to substances which occur normally in the body. Adrenaline (epinephrine, Figure 1) is the hormone which causes increased wakefulness and increase in blood pressure, heart rate and respiration, and is released from the adrenal gland in response to fear or excitement. Norepinephrine (Figure 1) is an important neurotransmitter, or "brain hormone". Both of thse compounds are derived from the essential amino-acid tyrosine, by enzymatic hydroxylation and decarboxylation to form the highly active norepinephrine, which is then stablized by methylation to form the less active epinephrine. Another important neurotransmitter is dopamine (Figure 1). This substance is also derived from tyrosine *via* the dihydroxamino-acid, L-Dopa, and a deficiency of this nerotransmitter causes Parkinson's disease. These compounds are all members of the family of β -phenylethylamines, which in general have central nervous activity. Note how "mere molecular modification" changes the properties of these molecules. Methylation at the *alpha*carbon increases activity by slowing down metabolic degradation of the amine group. Methylation at the nitrogen decreases activity.

A second group of CNS active agents are members of the *Beta*aminoethylindole class (Figure 2). The simplest of these is tryptamine, a mild CNS stimulant which can occur naturally. Conversion of this to dimethyltryptamine (Figure 2) produces a powerful psychotomimetic. This compound is closely related to two other naturally occurrring hallucinogens, bufotenin, found in toad skins and certain plants along the Orinoco river, and psilocin, whose phosphate ester is psilocybin, the active principal of the Mexican sacred mushroom ("God's flesh") *Strophariaceae agaricales* (1). These compounds are structurally related to the normal brain hormone, serotonin (Figure 2). Serotonin, or 5-hydroxytryptamine, was originally identified as "enteramine" in the 1930s, a stimulatory substance present in the intestine which caused constriction of intestinal tissue. Its structure was determined in 1949, and its presence in brain in low concentration reported in 1952. At that time it became the subject of intense investigation, so that in 1965 alone, over one thousand papers on serotonin appeared in the scientific literature (3). It turns out that serotonin is widely distributed, occurring in many plant and animal tissues, such as banana skins. It is produced in the brain by decarboxylation of 5-hydroxytryptophan, an amino-acid formed by hydroxylation of the essential amino-acid tryptophan (Figure 2). However, perenteral administration of serotonin does not have any effect on the brain, as it does not pass through the blood-brain barrier. An excess or deficiency of serotonin is held responsible for many mental conditions. It is reasonable to assume that abnormal metabolism of serotonin,

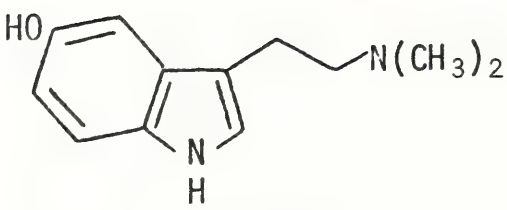
involving N-methylation, might produce the powerful hallucinogen bufotenin, thus causing some mental disturbance. However, this possibility has not been proven.



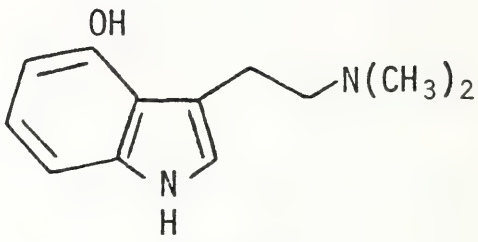
tryptamine



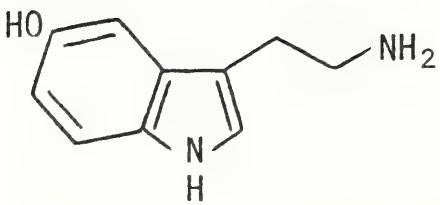
dimethyltryptamine



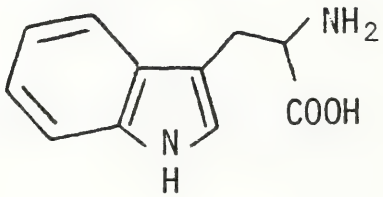
bufotenin



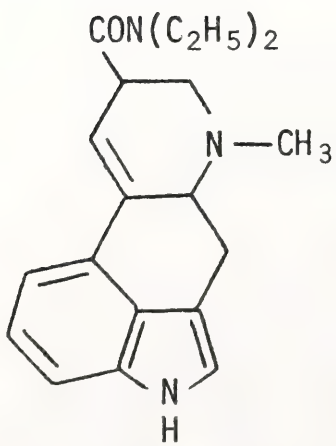
psilocin



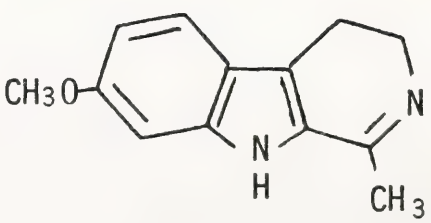
serotonin



tryptophan



LSD



harmaline

FIGURE 2.

The most potent hallucinogen known is d-lysergic acid diethylamide (LSD, Figure 2). It was discovered by Hoffman, who accidentally inhaled the dust of some of this recrystallized synthetic lysergic acid derivative. Later research established the fact that LSD was about 20,00 times as potent as a psychotomimetic agent as mescaline, being active at microgram levels (4). It is interesting that the active principal of *Rivea corymbosa*, or ololiuqui, a hallucinogenic plant used by Central American Indians, and known since the sixteenth century, also contains lysergic acid amides, although this fact was not established until 1960 (4). The amides present in ololiuqui are not so potent as LSD, however. Another alkaloid, from the leaves of *Malpighiaceae*, was used by South American Indians to prepare a hallucinogenic drink, called "ayahuasca" or "caapi" (1). It contains harmaline (Figure 2) a compound which found some use by physicians early in this century as an antidepressant. It is a powerful monoamine oxidase (MAO) inhibitor, and excess causes hallucinations, so it is no longer used clinically. It should be noted that both the lysergic acid derivatives and the harmala alkaloids are *beta*-aminoethylindole derivatives, although they differ by being held in different rigid structures.

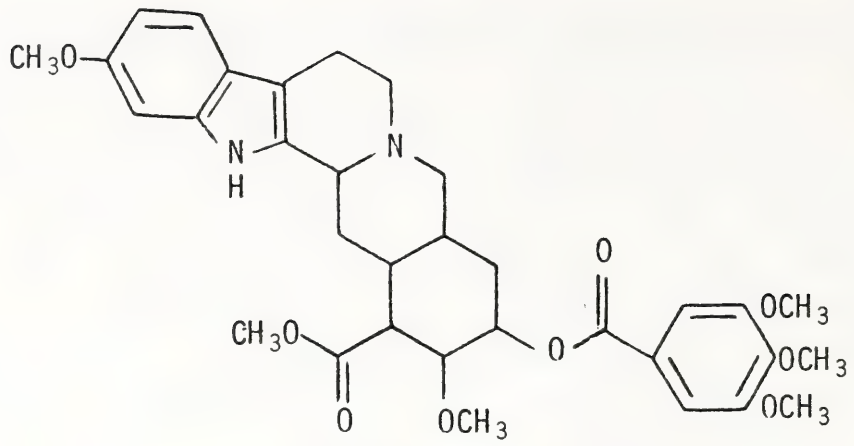
Tranquilizing Agents

We should now consider what happened to cause the sudden drop in hospital bed occupancy by mental patients which occurred in 1956. Although serotonin was under active investigation, and substances causing mental disturbance were well-known in folk medicine, terms such as "psychopharmacology", and "hallucinogen" had not been coined. The first tranquilizers or ataractic agents, reserpine and chlorpromazine, were discovered by accident, and it was these two which accounted for the spectacular decrease in hospitallization of mental patients.

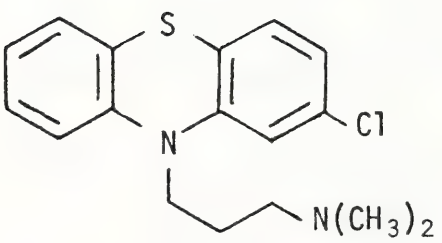
Extracts of the plant *Rauwolfia serpentina*, or Snake root, had long been used in India by holy men, to induce a trance-like condition during meditation. Colicky babies could be calmed with it, and it was used by Hindu physicians to lower blood pressure in patients with hypertension. Its use in the treatment of insanity by the Hindus is mentioned in western literature as early as 1755 (1). In 1947, Emil Schlittler and co-workers in Ciba, in Switzerland, began to investigate the alkaloids of *R. serpentina*, and by 1952 they had isolated and crystallized reserpine (Figure 3). Soon afterward pharmacologists reported that reserpine had both tranquilizing and antihypertensive properties. In testing on human patients, it was observed that the drug not only lowered blood pressure, but relaxed the tensions and anxieties which often accompany hypertension. In 1954, it was reported that reserpine was useful in treating psychotic patients, particularly those who are severely agitated and hyperactive. Note that reserpine (Figure 3) also belongs to the family of *beta*-aminoethylindoles, like those in Figure 2, but has a second complex portion of the molecule.

Chance, plus some astute clinical observations of the action of a drug useful for another purpose, played a major role in the discovery of the tranquilizer chlorpromazine [2-chloro-10(3-dimethylaminopropyl)phenothiazine, Figure 3]. Related phenothiazine derivatives had potent antihistaminic activity, and in searching for structural modifications of this drug, chlorpromazine was synthesized and found to have utility in motion sickness, but was very sedating. It was marketed in the United States for the treatment of nausea and vomiting in 1954, but it was soon discovered that its greatest utility was in the treatment of psychotic states. It is known that both reserpine and chlorpromazine can block the effects of LSD.

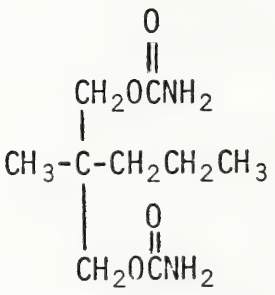
Still a third compound which had useful CNS effects was introduced in 1955, under the name Miltown (meprobamate, Figure 3). This was a mild "antianxiety" agent, or minor tranquilizer, which also has muscle relaxant properties. It was originally



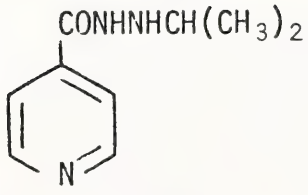
reserpine



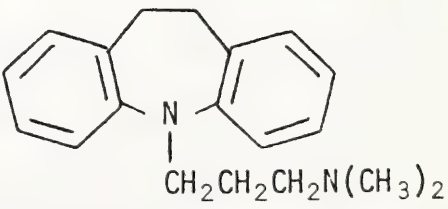
chlorpromazine



meprobamate



iproniazid



imipramine

FIGURE 3.

dispensed as an "over-the-counter" drug, and was widely used. It was the wide use of tranquilizers which prompted Dr. Nathan S. Kine, of Rockland State Hospital, to say,

> "A snarling vicious animal can be transformed by a few milligrams of a chemical into a friendly tranquil happy pet - a pleasure to have in captivity, but wouldn't last ten minutes in the jungle! Mankind may tranquilize itself into oblivion" (2).

It was the effect of known tranquilizers on animals that allowed the development

of second and third generation mild tranquilizers, such as the benzodiazepines (Valium, Librium, etc.). The pharmacologists now divide the ataractic agents (tranquilizers) into two groups, the major tranquilizers, (antipsychotic or neuroleptic agents) such as reserpine or chlorpromazine, and the minor tranquilizers, or antianxiety agents, such as meprobamate or benzodiazepam.

Antidepressants

Clinical reports on antidepressants, or analeptic agents, the so called psychic energizers, appeared in 1957, only a few years after the discovery of the antipsychotic drugs. There are two major classes, the MAO inhibitors, and the phenothiazine alalogs. Both were discovered accidentally, during searches for other drug types. During clinical studies of iproniazid (Figure 3) as an antituberculosis agent a mood-elevating effect of this drug was seen. It was soon found that iproniazid was a potent MAO inhibitor, thus preventing the destruction of norepinephrine and serotonin in the brain, and preventing the fall of these biogenic amine levels induced by reserpine. It was therefore used in the treatment of depression. However, iproniazid and related MAO inhibitors can cause severe rises in blood pressure, and they are not widely used today.

The tricyclic compounds structurally related to the phenothiazine class of antipsychotic agents (e.g. chlorpromazine, Figure 3), of which imipramine (Figure 3) is the primary example, were also discovered accidentally, while searching for antihistamines, sedatives and analgetics. The discovery of chlorpromazine prompted the testing of imipramine as an antipsychotic drug. It was relatively inactive in this regard, but instead appeared to have specific therapeutic value in the treatment of depression. Imipramine and related compounds are now the drugs of choice in treating depression. The earlier treatments involved the use of the hallucinogens harmaline and amphetamine, as previously noted.

Availability of New Drugs

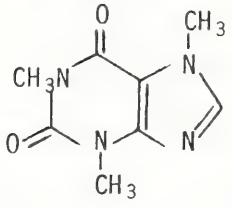
The history of the discovery of the psychopharmacological agents illustrates the fact that for new breakthroughs in drug therapy to occur, it is important that new drugs be available for human administration. Without reserpine for high blood presssure, or chlorpromazine as an antihistaminic, their action on mentally disturbed humans would not have been detected. Animal tests were only useful after the establishment of the pharmacological activity. In 1962, the Food and Drug Administration adopted new regulations requiring proof of efficacy as well as safety, before a new chemical entity could be introduced into clinical use. This reduced the number of new chemical entities introduced as drugs by more than half, 641 in the fifteen year period 1947-1962, versus 247 in the fifteen year period 1962-1976, as reported by the Pharmaceutical Manufacturers Association. Because a drug is not equal or more potent than a currently used drug does not mean that it will not be useful, and it may well have other more valuable properties.

Commonly Used Central Nervous Agents

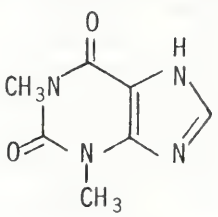
The availability of these central nervous agents led one pharmacologist to predict, "Soon people will titrate themselves awake with an analeptic agent, and at the end of the day, relax with an ataractic agent." However, people have long practiced that very thing. A couple of cups of coffee gives one enough central nervous stimulant, caffeine (Figure 4), to start the day wakeful, with perhaps booster doses in the middle of the morning and at noon. In the late afternoon, one or two cocktails produces a blood level of about 0.05% blood volume of alcohol, which induces a relaxed state mentally and a warm feeling due to mild peripheral dilation. Indeed caffeine is the most widely used drug in the world. In the U.S. we consume about seven million

kilograms per year. Many soft drinks, both brown and white, contain from 25 to 55 mg. of caffeine per ten ounce container. The toxic does, or LD_{50}, of caffeine is 150 mg/kg in rats. This is about the amount present in one cup of rich brewed coffee, so an average one hundred fifty pound human might die after consuming seventyfive cups of strong coffee at one sitting. Indeed, it was illegal to drink coffee, a dangerous drug, in Arabia in the fifteenth century.

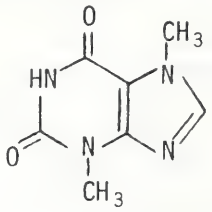
It is instructive to compare the activity of the three xanthines commonly present in both coffee and tea. The other two are theophylline and theobromine. All three have diuretic properties, and effect the brain, heart, and skeletal muscle. However, the minor molecular modifications shown by the varying positions of methyl groups (Figure 4) causes interesting differences in their activity. Caffeine, which is present as the major constituent of the xanthine mixture in coffee, exhibits predominantly central nervous activity. Theophylline was used clinically as a diuretic, since its effect on the kidneys and heart rate is more pronounced, while theobromine has a greater effect on skeletal muscle and as a vasodilator. Since, while tea does contain caffeine, the other two xanthines are the major constituent of the alkaloids in tea, drinking tea is more apt to be relaxing, causing a warm feeling. Thus coffee to wake up in the morning, and tea to relax in the afternoon, have a sound pharmacological basis.



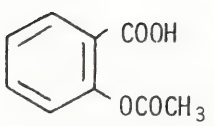
caffeine



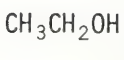
theophylline



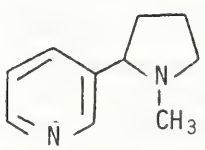
theobromine



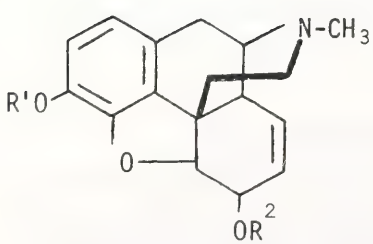
aspirin



ethanol



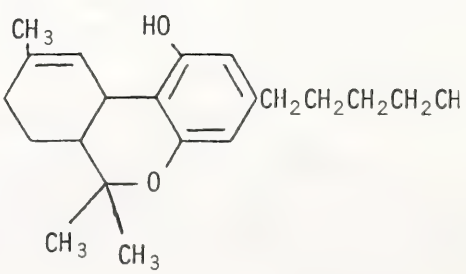
nicotine



morphine, R'=R^2=H

codeine, R'=CH_3, R^2=H

heroin, R'=R^2=CH_3CO



Δ'-3,4-*trans*-tetrahydrocannabinol

FIGURE 4.

Aspirin, or acetylsalicylic acid (Figure 4) is another widely used drug which has been shown to have mild CNS activity. While commonly used as an analgetic, or pain killer, it has many other activities. One of these is as a mild tranquilizer, actually counteracting the effects of the CNS stimulant tryptamine on the EEG of brain-canulated cats. Thus, for a tense and nervous person, "two aspirin and a nice cup of tea" is good medicine.

Another widely used drug is alcohol (ethanol, Figure 4). This is a very simple compound, and might be classified as a food, since its metabolism produces energy, and its carbon atoms are incorporated into body fat. However, it has various pharmacological activities, and has been used as a drug since ancient times. Alcohol is not a stimulant, as some believe, but is instead a depressant, and can act as a general anesthetic in high dosage. It was so used for surgery in early days. The apparent stimulation of the CNS, observed as the cocktail hour progresses from quiet clusters of friends at the beginning to noisy and boisterous behavior as the evening wears along, is in fact due to depression of the higher inhibitory brain centers, thus removing common inhibitions. Another effect of alcohol is vasodilation, causing a warm flushed skin. This can be beneficial to the angina sufferer, as it relieves the heart muscle, but heat loss is increased. Therefore consuming alcohol while out in the cold can be dangerous. Alcohol also stimulates gastric secretion at low concentration, but inhibits it at higher concentration. It is not always because the canapes are all gone that the late-stayers at the party quit eating and concentrate on drinking.

At 0.05-0. 10% blood alcohol, most people have a feeling of well-being, warmth of skin, and relaxation, with a loss of minor aches and pains. This blood level is equivalent to two to four ounces of 100 proof spirits consumed all at once. Another two ounces will raise the blood alcohol to 0.15%, at which concentration at least one half of the population will be intoxicated, that is loss of muscular coordination and slurred speech. Since the body ordinarily can metabolize about two ounces of 100 proof spirits in one hour, the wise drinker restricts the intake to no more than two drinks containing two ounces of proof spirits (the average cocktail) during the first hour, and no more than one drink per hour thereafter. He never drinks at the ball-game, rather waiting to dilate his peripheral vessels in front of the fire, where he can absorb the heat rather than lose it.

Nicotine (Figure 4) is another drug commonly used. It is highly active, and can be taken in small dosage by smoking. At low concentration, it has several effects. It is a central nervous stimulant, and increases heart rate and respiration. However, at high dosage, as by direct administration, these effects are reversed, resulting in mental depression, and paralysis of respiratory centers, resulting in death. However, continued use results in a high degree of tolerance. The compound is quite toxic: one cigar may contain enough nicotine to kill two men, if administered by intravenous injection.Two other ancient, but less commonly used drugs are the opium alkaloids (morphine, codeine and heroin, Figure 4) and the cannabanoid compounds found in hashish (*Cannabis indica*) and marijuana (*Cannabis americana*). These two classes of compounds have quite different effects. Opium was used for its sedative or narcotic effects, and the active principal, morphine, has valuable medical use as a powerful analgetic. Cannabis, on the other hand has no comparable medical benefit, and is generally used for its hallucinogenic properties. Its supposed beneficial effects on glaucoma have not been born out in tests with the pure active principal, delta-1-3-4-*trans*-tetrahydrocannabinol (Figures 4). The red oil, extracted fom both *Cannabis indica* and *Cannabis americana*, contains a mixture of geometric and stereoisomers, of which delta-1-3-4-*trans*-tetrahydrocannabinol is one of the more active. Synthetic homologs have been

prepared which are as much as five hundred times as potent as the natural extract. This drug has the effect of releasing inhibitions, but without effecting coordination. Currently there is much research investigating analogs and related structures, and a number of interesting leads to a variety of drug actions have been obtained. The value of marijuana may be in providing a molecular structure pattern which will lead to new classes of useful drugs.

In summary, then, we have seen that the availability of chemical compounds which can be used in humans can sometimes lead to new treatments of intractable diseases. Further, it was shown that minor molecular modifications, such as the introduction of a methyl group at a strategic location on a molecule, may lead to subtle differences in the biological activity of a compound. Finally we have shown that molecules with similar molecular structure frequently have related biological activity.

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ANTHROPOLOGY

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ABSTRACTS

Analysis of Three Tool Kits for the Bluegrass Site (W162), a Late Archaic French Lick Phase Site in Warrick County. C. Michael Anslinger, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.—Three tool kits recovered from burial associations during the 1983 test excavations at the Bluegrass Site (W162), a Late Archaic, French Lick Phase, site in Warrick County, produced tools and adornments of chert, ground stone, bone, antler, teeth and shell. Functional interpretations formulated from use-wear attributes indicate most tools served in the hunting-butchering-hide processing complex. Furthermore, projectile point forms are more typically associated with Late Archaic shell mound and related sites in Kentucky and Tennessee. It is suggested that influences from the Middle South should also be recognized as contributing to the stylistic dimensions of the French Lick Phase, in addition to those from the Helton Phase in Illinois.

Final Report on the Excavations at Fox Island Site (12AL121) Allen County, Indiana. Diane E. Beynon, Department of Anthropology, Indiana-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.—Recent data recovered from the final season of excavation at the Fox Island Site (12AL121) revealed the existence of at least two projectile points in direct association with the cremated human burial discovered the previous year. The burial (F3) was reopened this season and diagnostic fragments of skull, vertebrae and one distal phalange support its identification as a human burial. Additionally, two Raddatz-like projectile points were found directly associated with the burial. Initial analysis indicates that the points were thermally altered after manufacture. This is attested to by spalling and the generally friable nature of the chert. While the thermal alteration partially obscures the ability to diagnose chert type, all indications suggest that the projectiles are of Liston Creek variety. Although a Middle Archaic Stage is indicated for the age of the burial because of the Raddatz-like points, an absolute age for the burial will be decided after determination of radiocarbon dates. To date, this association of Archaic projectile points with a human cremation is the first of its kind to be recovered from a systematic excavation of an archaeological site in Northeastern Indiana.

Provenience and Use of Chert from the Ditney Hills, Warrick County, Indiana. Mark Cantin and Robert E. Pace, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.—Survey and excavation in the northwest region of Warrick County, Indiana recovered tools and debitage of a variety of chert types, including types believed to have originated in the local Ditney Hills area. Geologically, the chert outcrops at the top of the West Franklin limestone member of the Shelburn Formation, and at the bottom of the Ditney Coal member of the Patoka Formation. Both are

associated in the McLeansboro Group of the Pennsylvanian system. Preliminary reconnaissance of exposed bedrock has identified thin shale and coal beds, ferrous sandstones, and cherty limestones. Samples of low-quality, limey chert are known to have been utilized for tools by Late Archaic, French Lick Phase cultures. However, a fine grained, high-quality chert is reported to be found on eroded slopes of Ditney Hill. This presentation reports the source, description, and use of the local Ditney cherts.

Bone and Antler Industry at a Late Archaic, French Lick Phase Site (W162) in Warrick County. MARY ELLEN CARPENTER and ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——Bone, antler and teeth constituted a significant source of raw material for Indians of the Late Archaic, French Lick Phase in southwestern Indiana. In addition to extracting marrow and grease to supplement diets, a variety of tools, adornments and containers were fashioned from skeletal remains of the animals. Artifact and waste remains recovered from the Bluegrass Site (W162) of Warrick County are discussed and compared with those recorded at other Late Archaic sites in the region. It is suggested that types and frequencies of bone tools reflect internal organization at specific sites, and external relationships between sites.

French Lick Phase Burials and Mortuary Customs of the Bluegrass Site (W162), Warrick County, Indiana. MARCIA ELLIOTT and ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——Twelve burials excavated during two summer seasons (1982 and 1983) of fieldwork at the Bluegrass Site (W162) in Warrick County, Indiana offer insights into the biological information and mortuary customs of the Late Archaic, French Lick Phase. The biological information includes the occurrence of various discrete traits and pathologies. The description of mortuary customs relates information on the burial position, presence of artifacts, and age and sex assessment of the individuals at the Bluegrass Site.

Archaeological Resources and Riverbank Erosion in Western Indiana. MISTY JACKSON and ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——Loss of archaeological sites to erosion along riverbanks is generally recognized but poorly understood in terms of numbers, types and implications for reconstruction of cultural systems. Classic examples of loss include the Raaf Site along the Ohio River in Spencer County and the Bone Bank Site along the Wabash River in Posey County. Many other sites less obvious to the public but as critical for reconstructing cultural systems have been, and continue to be, lost to migrating banks. Reconnaissance along banks of the Wabash and tributary rivers has identified a variety of surface and buried sites, ranging from temporary camps to large villages, and representing Archaic, Woodland, Mississippian and Historic components. Data from these sites and from studies of the dynamics of bank migration are being combined to provide a means of predicting the numbers, types and rates of archaeological site loss.

Prehistoric Settlement Patterns in Northwest Warrick County, Indiana. DANIEL P. THIEL and ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——As part of an archaeological survey for site patterns in southwest Indiana, six study areas are being examined with fieldwork for four essentially completed this past summer. This paper will report the initial analysis of data collected from the Elberfield area in northwest Warrick County. Approximately 1000 acres were systematically examined including upland flats, upland slopes, and floodplain. Over 100 prehistoric sites were located. Information recovered from this survey, previously recorded sites and test excavations at the Bluegrass Site (W162), shows the area as most intensively used by the Late Archaic with sites concentrated on the upland

flats and upland slopes. Few sites are found on the floodplain. From their distribution and from data on former natural resources, a model of settlement and subsistence comparable with others for the Upper Patoka Lake area and southeastern Indiana is being constructed.

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ABSTRACTS

Cytofluorometric Measurements and Nuclear and Nucleolar Morphological Changes in Successive Epidermal Cells in Response to *Botrytis allii* Infection. Pradeep K. Bhattacharya, Department of Biology, Indiana University Northwest, Gary, Indiana 46408, and Aristotel J. Pappelis, Department of Botany, Southern Illinois University, Carbondale, Illinois 62901.——Six nuclear indices were cytofluorometrically measured across 40 consecutive cell-rows in *Botrytis allii* infected onion bulb leaf base outer epidermis. Mycelium had penetrated 10 to 15 rows of cells adjacent to the inoculation site. Host cells in the infected region contained the least amount of total nucleic acids, DNA, RNA, total nuclear protein, histone, and non-histone protein while those 20 to 30 cells beyond the infected area contained the great amount of these. Nuclei in the infected area were pycnotic and the nucleoli in these were small, round, and generally without nucleolar vacuoles (indicating physiological inactivity). Cells in 20 to 30 cell-rows beyond the infected area contained normal nuclei and the nucleoli in these tended to be oval or round, twice the diameter of inactive round nucleoli, and, usually contain many nucleolar vacuoles (indicating physiological activity). Nuclei and nucleoli in the cells between those in infected areas and 20 to 30 cell-rows beyond were intermediate in nuclear and nucleolar traits. We conclude that *B. allii* kills host cells, greatly reduces the macromolecular content of the host nucleus, and inactivates nuclei and nucleoli in advance of the spread of mycelium in host tissue.

Viability of Sixty-one Year Old Spores of *Marsilea quadrifolia*. William W. Bloom, Valparaiso University, Valparaiso, Indiana 46383.——In 1952 the author reported on the viability of spores of *Marsilea quadrifolia* that were thirty years old. At that time seven of the ten sporocarps tested contained viable megaspores and produced embryo sporophytes. This year three remainig sporocarps (now 61 years old) from that collection were tested with the following results: one released spores from the sori but no spores were viable; one retained the spores in the sori and no spores were viable; one released all spores but only sixty-two of seventy-eight megaspores were viable and produced normal gamteophytes. Only a few microspores showed evidence of viability and no functional sperm were observed. No embryo sporophytes were produced.

Abscisic Acid-Kinetin Interactions on Lipid Bilayers. Paul Hester and William Stillwell, Department of Biology, Indiana University-Purdue University at Indianapolis, Indiana 46223.——Although plant hormones are known to alter many physiological processes, a precise mode of action has not been described for any of them. The hormones kinetin and abscisic acid (ABA) have been shown to affect the permeability of several plant membranes, often in an antagonistic manner. Because of the complex nature of biological membranes it has not been possible to deduce the nature of these

hormone-membrane interactions. We have, therefore, used the well-defined, protein-free artificial bilayer systems (liposomes) in place of biological membranes to more accurately assess the effects of kinetin and ABA on membrane permeability.

ABA is shown to enhance the permeability of crude egg lecithin bilayers to urea, erythritol and water. The effect is pH dependent (undissociated ABA is much more effective) and requires the presence of phosphatidyl ethanolamine (PE) in the bilayers (no effect is noticed with PE-free, dimyristoylphosphatidylcholine bilayers). Kinetin also enhances permeability of similar bilayers. When the membranes containing PE are exposed to the two hormones simultaneously, however, a clearly antagonistic effect is seen with kinetin reversing the ABA-induced permeabilities. On the basis of these experiments we propose that undissociatead ABA enhances membrane permeability by interacting with PE, possibly forming channels which in turn are blocked by kinetin. This model can explain many of the rapid-time physiological effects of these two plant hormones.

Evidence for Increased Primary Productivity Under Dynamic Conditions. JEFFREY KING and AUSTIN BROOKS, Wabash College, Crawfordsville, Indiana 47933.——The estimation of the primary productivity in an aquatic habitat has long been accomplished by the light and dark bottle method. The accuracy of this method was questioned by John H. Rodgers Jr. (1976, 1978). In 1978 our laboratory began to investigate primary productivity estimations under various conditions. We propose that the current light and dark bottle method may underestimate the aquatic primary productivity.

Cultures of *Oscillatoria* were grown in a sterile, synthetic media (Alga-grow Freshwater, Carolina Biological Supply) for seven to ten days, at 23 °C and a light intensity of about 300 ft.c. Through agitation, the cultures were made homogeneous. The homogeneity of the culture was confirmed by correlating the optical density, measured at 525 nm, with the total protein, and chlorophyll *a* content. Chlorophyll was extracted using the acetone/DMSO technique, while total protein was determined using the Lowry method. The cultures were then placed under various physical parameters; both static, and dynamic, and incubated with $NaH^{14}CO_3$ for 30 minutes at 23 °C, with a light intensity of about 300 ft.c.

We observed an increase in the primary productivity under dynamic conditions of nearly 20 percent over that observed in the static environment. However, after the current speed exceeded 110 cms^{-1}, productivity decreased to a level lower than the static productivity. This was most pronounced at a speed of 145 cms^{-1}. These current speeds are similar to those that *Oscillatoria* may encounter in nature.

While the reduction in productivity at fast current speeds is reproducible, we are unsure of its cause. Through a dilution and enrichment scheme we feel that the nutrient concentration is not the controlling factor in this process. We have observed that by first stressing the cultures (prestirring them at 145 $cms,^{-1}$) for various periods of time, then carrying out our normal dynamic incorporation procedure, that *Oscillatoria* appears to show an ability to adapt to the turbulent environment. After approximately 25 minutes of high speed prestirring, the cultures exhibit an estimated primary productivity that approaches that obtained under static conditions.

A Comparative Study of Photosynthetic Rates in Deep (30m) Shallow (1-2m) Water Species of Algae. ROSALIE KRAMER, Department of Biology, Indiana University East, Richmond, Indiana 47374.——Preliminary studies of the comparative photosynthetic rates of deep (30m) and shallow (1-2m) water species of tropical marine algae indicate significant differences in the plant's photosynthetic mechanisms. As plants growing at different depths utilize different wave lengths and different pigment systems, this was

to be expected. Algae were selected from the families chlorophyta, rhodophyta, and phaeophyta. The study was carried out at Glover's Reef Atoll, Belize, Central America. This study attempts to demonstrate possible adaptability of algae to differing photosynthetic conditions by "transplanting" deep water specimens into shalow water and shallow species into deep water. The algae were maintained in the new environment for one month and comparative photosynthetic rates were taken on a weekly basis. Readings were based on the amount of O_2 evolved in one hour in a standard 300 ml B.O.D. bottle as read with a dissolved oxygen probe attached to a portable Orion pH meter.

Sequential readings over the month-long period indicated differences in the ability of different species of algae to acclimate to the new habitat.

Further work in terms of a long-term study is needed to validate results and to collect data on additional species.

The Effects of Hormone Treatment on Superoxide Dismutase Activity in Etiolated Decapitated Pea Seedlings. JULIE A. OLSEN and CURTIS R. COOK, Wabash College, Department of Chemistry, Crawfordsville, Indiana 47933.——Tissue taken from the cut surface of etiolated decapitated pea seedlings shows rapid decline (within 30 minutes) in superoxide dismutase activity to approximately 40% of the original level. Protein concentrations also fall within similar time span to approximately 70% of the initial concentration. The tissue recovers about 90% of the protein and 50% of the superoxide dismutase activity within 2.5 hours of decapitation. Treatment of the cut surfaces with solutions of indole acetic acid, kinetin gibberellic acid or ethylene gas indicate that both indole acetic acid and kinetin provide some selective protection for superoxide dismutase from general proteolysis. Indole acetic acid, kinetin and gibberellic acid also appear to enhance the rate of protein synthesis following wounding.

Potassium Transport Defective Mutant Strains of ***Chlamydomonas reinhardtii*** L. DAVID POLLEY, Wabash College, Crawfordsville, Indiana 47933.——Mutants of *Chlamydomonas reinhardtii* which exhibit a dependence on abnormally high concentrations of potassium for growth have been isolated. These have been characterized genetically and physiologically. Results of genetic analysis show that the potassium dependent phenotype is inherited as a nuclear gene. Characterizations of potassium transport show that wild type cells have two potassium transport systems and that the mutant strains lack one of the transport activities (a potassium "scavenging" activity).

Potassium transport defective strains also were examined for possible pleiotrophic effects of the lesion in the transport gene. Mutant strains were observed to stop swimming after four hours of potassium starvation. The effects of potassium starvation on the cell's ability to mate is also being explored. The potential these other pleiotrophic effects may have in developing enrichment schemes for future mutant hunts will be discussed.

Pisolithus tinctorius **Inoculation Enhances the Nursery Production of** ***Quercus rubra*** **L. Seedlings.**——P. E. POPE, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907 and J. D. RHODES, Research Associate, Texas A & I University, Kingsville, Texas 78363.——Nursery beds planted with *Quercus rubra* L. were inoculated with vegetative mycelium of the mycorrhizal fungus *Pisolithus tinctorius* (Pt) or autoclaved inoculum at a rate of 200 ml/0.1 m^2 in early May of 1980, 1981 and 1982. Both treatments received the same amounts of irrigation and fertilization during the growing season. All seedlings from the four 1.2 x 1.9 m replicates were lifted in mid to late November of each year and graded by nursery standards for height and diameter for marketability. In addition, the seedlings were separated into four size classes and subsamples taken to determine total dry weight, root/shoot

ratio, methanol soluble carbohydrates and extent of mycorrhizal infection. Inoculation of red oak nursery beds significantly increased the number of salable seedlings and the average total dry weight/seedling each of the three years. Root to shoot ratio and methanol soluble carbohydrates of inoculated seedlings were significantly greater than the control in 1980 and 1982. Enhanced seedling growth is influenced by the mycorrhizal inoculation treatment but percent root colonization by the mycorrhizal fungus is poorly correlated with many of the seedling growth parameters. Mycorrhizal development on seedling roots inoculated with Pt was significantly greater than the control for all years.

Cellar Storage Shows Promise for Preserving Viability of Black Walnut Seed. ROBERT D. WILLIAMS, U.S. Forest Service, Bedford, Indiana 47421.—Black walnut (*Juglans nigra L.*) seeds from nine southern Indiana seed trees were collected in the fall of 1978 and either sown into Vallonia Nursery seedbeds soon after collection or stored one full year in soil pits or in root cellars, then sown at the nursery in the fall of 1979.

Differences in germination attributable to both seed source and storage facility were statistically significant at the 1-percent level. Also, the interaction between seed source and storage facility was significant at the 10-percent level. Some seed sources germinated best after pit storage while others germinated best after being stored in one of the root cellars.

Germination of some seed sources was more than 50-percent after a full year in cellar storage. So cellar storage has the potential for cheap, effective storage of black walnut seed for one year.

Seed Source Affects Black Walnut Seedling Growth More Than Mycorrhizal Inoculation. ROBERT D. WILLIAMS, U. S. Forest Service, Bedford, Indiana 47421.—In 1980 containerized black walnut (*Juglans nigra L.*) seedlings from four local families and one mixed seed source, both inoculated and non-inoculated with vesicular-arbuscular mycorrhizae, were outplanted into an old field in southern Indiana.

Fourth year results from the study show that seed source, even though all were local families, has had more effect on seedling growth than mycorrhizal inoculation.

Fourth year survival was not affected by seed source or inoculation. Although small, height differences attributable to seed source are statistically significant at the 1-percent level and diameter differences attributable to seed source are significant at the 5-percent level. Neither height nor diameter differences attributable to mycorrhizal inoculation are statistically significant.

Immunocytochemical Identification of Laticifers. KATHRYN J. WILSON, and BRUCE H. PETERSEN, Department of Biology, Purdue University School of Science, Indianapolis, Indiana 46223, and DAVID D. BIESBOER, Department of Botany, University of Minnesota, St. Paul, Minnesota 55108.—A sensitive immunocytochemical method for the identification of laticifers has been developed. To prepare latex antiserum latex serum was prepared from whole latex of wild *Asclepias syriaca* plants and injected into rabbits. The IgG fraction of the rabbit serum was separated by ion exchange chromatography and antibodies not specific to laticifer cells were removed by absorption of the IgG fraction with cells derived from liquid cell cultures of *A. syriaca* determined not to contain laticifers. Frozen sections of various laticifer-bearing plant material were mounted on slides. Sections were flooded with anti-latex antiserum followed by flourescein-conjugated IgG fraction goat anti-rabbit IgG to visualize laticifers. Positive flourescence was observed for laticifers in shoots and embryos of *A. syriaca* and *Stapelia bella*, and embryos of *A. tuberosa*. Laticifers did not fluoresce in shoots of *A. tuberosa*

and *Euphorbia tirucalli*, in embryos of *E. marginata*, or in petioles of *Musa pardisiaca* and *Cichorium intybus*. Controls prepared with uninjected rabbit serum were negative (no flourescence).

A Survey of Tree Growth in the Merry Lea State Nature Preserve, Noble County, Indiana. STEPHEN C. YODER and LARRY R. YODER, Merry Lea Environmental Learning Center of Goshen College, Goshen, Indiana 46526.——Line strip surveys in a 56 acre portion of the Merry Lea State Nature Preserve were conducted by Alton A. Lindsey in 1972. The site is well suited as a permanently protected example of an oak-hickory association that experienced earlier selective harvests but is now growing without further human disturbance. A re-survey of the same line strips in 1982 revealed an 8.6% reduction in stand density which represents a loss of 1.2 trees per acre per year. During the same period the basal area increased by 10.6% or 1.1 ft^2 per acre per year. Among 15 species present, white oak (*Quercus alba*) and pignut hickory (*Carya glabra*) showed the greatest decrease in stand density. All species except for pignut hickory increased their basal area at a rate that more than off set density declines. The presence of shade intolerant species and a disjunct distribution of sizes indicates past disturbance from harvests. In both surveys, shagbark hickory (*Carya ovata*) was the most frequent species followed by black oak (*Quercus velutina*), wild black cherry (*Prunus serotina*), white oak (*Quercus alba*), pignut hickory (*Carya glabra*), and sassafras (*Sassafras albidum*). Future studies at 10 year intervals will provide an important base for assessing species composition and growth patterns in similar ecosystems. The 1982 survey was supported by an IAS research grant.

Angiosperm Root Parasites of Indiana

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Introduction

There are 14 genera of parasitic angiosperms that occur in Indiana, with potentially more to be included. Mistletoe (*Phoradendron flavescens* (Pursh) Nutt.), of southern Indiana and dodder (*Cuscuta* sp.) are probably the more familiar examples of parasitic angiosperms; parasitism by these species confined to the host stem. This discussion concentrates on a different group that have received less attention, the root parasitic species. All are characterized by a morphological and physiological connection called the haustorium, a term used to describe a functionally similar structure of fungal pathogens. The majority of root parasites are not host specific, i.e., they indiscriminantly parasitize most herbaceous or woody species. Only in the past decade has any root parasite been shown as pathogenic towards arborescent hosts in the United States (i.e., *Seymeria cassioides* on *Pinus elliotii* 17), though species of *Striga*, *Orobanche*, *Aeginetia*, and *Alectra* have devastated such crops as maize, sugarcane, tobacco, and legumes throughout the world in warmer climates (9).

An objective of this paper is to discuss characteristics of some root parasites known to occur throughout Indiana. Haustorium morphology and anatomy will be reviewed. The ecological significance of root parasitism will also be emphasized.

Parasitic Plants in General

With the lone and debatable exception of a parasitic conifer found in New Caledonia (11) all parasitic vascular plants are dicotyledenous angiosperms. Plant parasitism has arisen in at least eight unrelated groups of dicots distributed worldwide (11):

1. Santalales (mainly the following three families: Olacaceae—25 genera, 150 species; Santalaceae—26 genera, 250 to 600 species; Viscaceae—7 genera; and Loranthaceae—70 genera, with a combined 1000 species)
2. Scrophulariaceae (210 genera, 3000 species) and Orobanchaceae (13 genera, 140 species)
3. Rafflesiaceae (7 genera, 27 species) and Hydnoraceae (2 genera, 10 species)
4. Balanophoraceae (2l genera)
5. *Cuscuta* of the Convolvulaceae (more than 150 species of *Cuscuta*)
6. *Cassytha* of the Lauraceae (less than 20 species of *Cassytha*)
7. Lennoaceae (3 genera)
8. Krameriaceae (1 genus, 15 species)

The Orobanchaceae, Rafflesiaceae, Balanophoraceae, and Lennoaceae are considered holoparasitic, i.e., their members are without chlorophyll, therefore depend totally on their host for nutrients and water. The remaining groups are hemiparasitic, or semiparasites, in that they are chlorophyllous and obtain some, if not all of the energy requirement through photosynthesis. The degree of parasitism varies between and within chlorophyllous parasitic species as some individuals within a parasitic population may even be autotrophic (2). Only the Loranthaceae, Viscaceae, and *Cuscuta* and *Cassaytha* species are stem parasites; the other groups parasitize roots. The Orobanchaceae, Santalaceae, and Scrophulariaceae are the only families of root parasites known to occur in Indiana.

Indiana Parasitic Plants

Genera which belong to the Orobanchaceae, Santalaceae, and Scrophulariaceae native or naturalized in Indiana are listed in Table 1. Those genera known to be root parasites are designated. The remaining genera, e.g., *Verbascum*, *Veronica*, and *Scrophularia* are apparently not root parasitic (24). At least 12 genera of root parasites are found in Indiana, all of which are herbaceous annuals, biennials, or perennials. Shrubby and arborescent root parasites are more prevalent in subtropical and tropical flora (11) and some are common throughout the southern United States (25).

TABLE 1. *Genera of parasitic (*—references follow) and non-parasitic Orobanchaceae, Santalaceae, and Scrophulariaceae native to or naturalized in Indiana (from 4; names revised according to 8).*

Orobanchaceae (11, 22, 40)
**Conopholis* Wallr. (30)
**Orobanche* L. (21)
**Epifagus* Nutt. (39)
Santalaceae (11, 23, 37)
**Comandra* Nutt. (20, 34)
Scrophulariaceae (11, 24, 26, 29)
**Agalinis* Raf. (28)
**Aureolaria* Raf. (44)
Bacopa Aubl.
Besseya Rydb.
**Buchnera L. (25)*
**Castilleja* Mutis ex L.f. (7, 15)
Chaenorrhinum (D.C.) Reicheno.
Chelone L.
Collinsia Nutt.
**Dasistoma* Raf. (32)
Gratiola L.
Kickxia Dumort.
Leucospora Nutt.
Linaria P. Mill
Lindernia All.
**Melampyrum* L. (3, 31)
Mimulus L.
**Pedicularis* L. (33)
Penstemon Mitchell
Scrophularia L.
**Tomanthera* Raf. (24)
Verbascum L.
Veronica L.
Veronicastrum Heister ex. Fabr.

The Haustorium

The haustorium is a morphological and physiological bridge, composed at least partly of living tissue, through which materials are transported from host to parasite. Emphasis is placed here on this structure because an understanding of it helps to elucidate the evolutionary origin and function of parasitism (11, 24). There is little chance of distinguishing most species as root parasitic unless the haustorium is evidenced. Root parasitic species appear normal above ground except for *Conopholis americana* (L.) Wallr. (squawroot, cancer-root), *Epifagus virginiana* (L.) Barton (beechdrops), and *Orobanche* sp. all of which are holoparasites.

The following observations are somewhat cursory since the haustoria among the various families and genera in Table 1 may differ in their origin, morphology and anatomy, function, or even mode of attachment (11). More detailed studies on specific genera are referred to in Table 1. An especially thorough, comparative study by Musselman and Dickison (24) included many of the species found in Indiana.

The haustorium varies in size within and between species depending on its age, the species parasitized, and the degree of penetration. It is very small (1.0 mm diameter) in *Pedicularis canadensis* and *Castilleja coccinea* and much larger (to 10 mm diameter) in some genera such as *Aureolaria* and *Dasistoma* (25). Santalaceae, Scrophulariaceae and Orobanchaceae haustoria are whitish to light colored, conical to hemispherical in shape or sometimes flattened. Annual growth of haustoria occurs in some species and also depends on the longevity of the host (annual host vs. perennial). Some haustoria remain for only one year. Only very small host roots are parasitized by some species, e.g., *Epifagus virginiana* (39). Haustoria of *Conopholis americana* are massive and much darker, forming on larger host roots and functioning for many years.

Haustoria occur either sporadically along a host root or clustered in large numbers. Over 2000 haustoria formed within 6 months by various species of *Agalinis* on a single, one year old host (25). In another study, an individual *Aureolaria pedicularia* produced 11,000 haustoria (44). Elliptical scars are sometimes evident on host roots where the haustorium has disappeared (14). Host roots commonly die distal to the point of attachment, or at least decrease in size (24).

A longitudinal section through a typical Santalaceous haustorium (transverse to host root) is illustrated in Figure 1. The two main sections are the outer periphereal

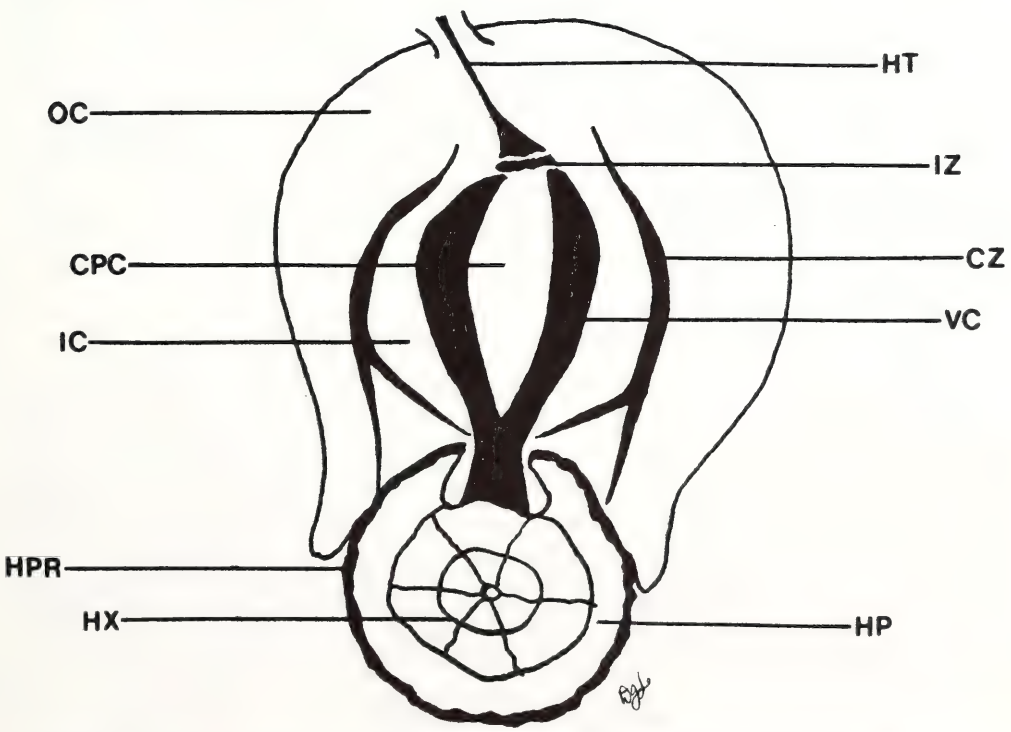

FIGURE 1. *Longitudial section of Pyrularia haustorium, transverse to host: CPC—central parenchymatous core; CZ—collapsed zone; HP—host phloem; HPR—host periderm; HT—haustorial tracheids; HX—host xylem; IC—inner cortex; IZ—interrupted zone; OC—outer cortex; VC—vascular core (from* 14).

or outer parenchymatous region and the axial region or inner core. The outer periphereal region is primarily parenchyma cells and may be superficially suberized. The main functions of this layer are: (1) to protect the inner haustorium tissue; and (2) to assist in the attachment of the haustorium to the host (6).

Three areas are delineated within this outer layer which are the outer cortex (OC), inner cortex (IC) and at least one layer of collapsed tissues (CZ). The outer cortex consists of closely packed cells with few intercellular spaces and often abundant starch grains. The tissues located between the collapsed layers(s) and the axial tissue constitute the inner cortex. The collapsed zone is a distinction of Santalaceous haustoria and a few other genera of root parasites, excluding the Scrophulariaceae (24).

Cortical or clasping folds are also apparent around the apex of the haustorium where it is affixed to the host root. These folds aid in protecting the internal haustorium tissues and in fastening this structure to the host. Prying folds, possibly with the aid of host tissue reaction, are responsible for the peeling back of host periderm and cortex, and help expose the host xylem.

The vascular tissue within the axial region is shown as an inverted flask-shaped area. Three areas are typical within the axial region: (1) the neck or track of vascular tissue which connects to the xylem of the parent (parasite) root (HT); (2) a hemispherically shaped, fairly homogeneous core of parenchyma in the upper body region (CPC); and (3) a tract of tracheary tissue which converges from the peripheary of the vascular core towards the intrusive organ of the parasite (VC). Five cell types constitute the vascular core: vessel elements (about 95% of cells), vascular tracheids, libriform fibers, parenchyma, and phloeotracheids (24).

A zone of scattered and disintegrated xylem elements may exist slightly above the widest expansion of the vascular loop. This zone of uniseriate strands of xylem dispersed in parenchyma is known as the interrupted zone (IZ), another characteristic feature of the Santalaceous haustoria (and only a few Scrophulariaceae). Though some observers have not noted this layer (e.g., 20, 37), others have had no difficulty showing its presence in many of the same species (42, 43). Failure to locate the interrupted zone is attributed to improper orientation of the haustorium during the sectioning process (12). The function of this zone poses further speculation since the translocation of various compounds from the host to the parent plant may be rather selective or impeded here (43).

Development of Haustoria

Haustoria result from a simple lateral extension of the primary root as a whole structure. The epidermis, cortex, and endodermis of the parasite root bulges out to form a protuberance which becomes the haustorium (43). Though haustoria are borne laterally along the parent root, this lateral root often senesces distal to the haustorium, making the haustorium appear as if it was terminal. There are five stages in haustorial development (taken directly from 24): (1) hypertrophy of the cortical parenchyma of the haustorial root; (2) attachment to the host root; (3) periclinal divisions in haustorium pericycle (development of vascular core); (4) penetration of host tissue; and (5) establishment of xylem continuity between host and parasite.

Host Parasite Contact

The contact between host and parasite xylem by the intrusive organ (endophyte), can be a fairly uniform line, or bluntly pointed, wedge-shaped structure. Both types are depicted in Figure 2.

The lack of crushed xylem tissue in the host in the zone of host-parasite contact

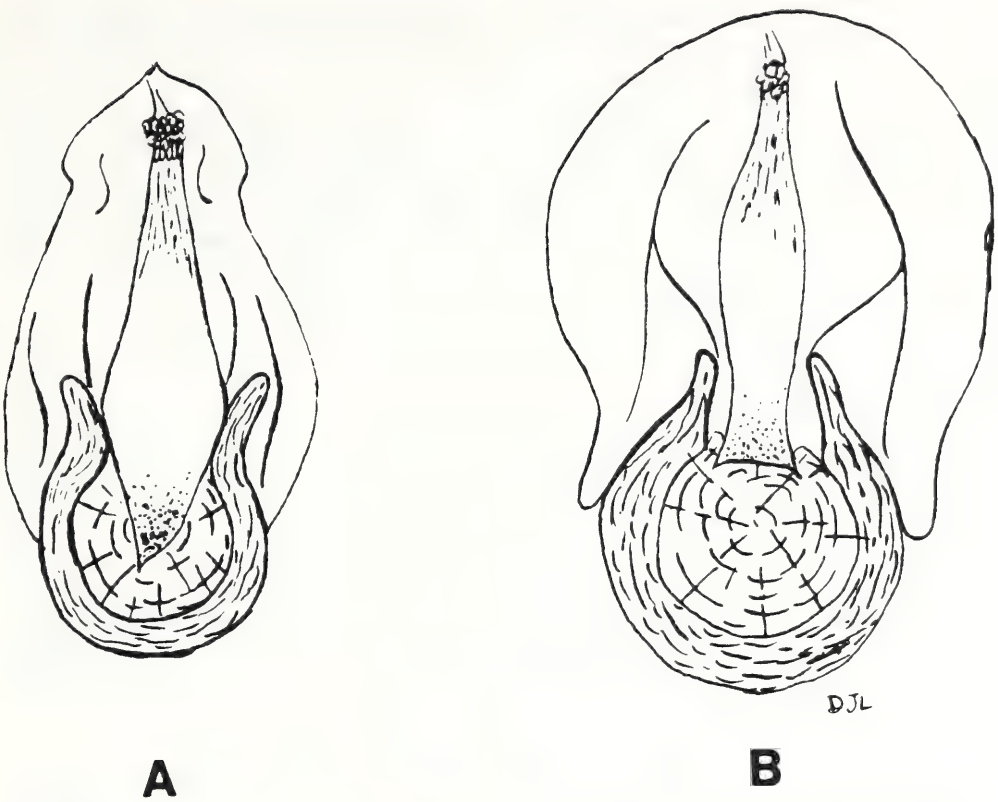

FIGURE 2. *Two paths of intrusion by haustorial xylem: A, wedge-shaped; B, uniform line of penetration (redrawn from 43).*

demonstrates that mechanical pressure has little or no role in the penetration process. Instead, enzymes allow penetration for the growing intrusive cells. A darkened area of cells between the host tissue and the intrusive organ results from the release of digestive enzymes in this region. Enzymes digest the host periderm and cortex but may be resisted by the lignified tissue of the host xylem (38).

Some investigators attribute these enzymes to the presence of a gland. The gland may be the only true diagnostic structure of the Santalaceous haustoria. However, some have never observed this structure, possibly because it exists only at an early stage in haustoria formation (12).

The actual connection of xylem between parasite and host is afforded by an apposition of the pit aperatures of the vessel elements in both members. The xylem of the parasite does not appear to directly penetrate the host xylem.

Though phloem has been located only in *Castilleja* (13), phloeotracheids occur within the area of xylem vessel members in the vascular core of Santalaceae and Scrophulariaceae (12). The importance of phloeotracheids is obscure, though these structures seem to further obstruct the intake of materials into the haustorium (12).

Function of Parasitism

The function of parasitism is perplexing. Musselman and Mann (26) suspect that water is an important factor between parasite and host, based on the occurrence of pronounced wilting taking place in hosts under water stress. Thurmann (41) also noted that host plants wilt first when both the parasite and host are subjected to moisture stress. Various *Cordylanthus* (Scrophulariaceae) species could grow in dry chaparral

and woodland savanna presumably because parasitism allowed these species to use water from their host (36). Parasitic plants in general are known to have high transpiration rates (11).

Many plants have developed a particular means for tolerating an inadequate moisture supply, such as thicker cuticles, bulliform cells, microphylly, sunken stomata, strong palisade development, stem and branch photosynthesis, deep rooting and adventitious roots (5, 10). Haustoria may be yet another adaptive structure which enables a species to survive under moisture stress. Increased haustorial frequency on more xeric sites has been noted for *Aureolaria pedicularia* (44).

Mann and Musselman (19) demonstrated that many species of root parasites in the Scrophulariaceae could grow to maturity from seed, without any host, as long as the parasites were fertilized regularly with nitrogen, phosphorous, and potassium. However, parasites without a host and no fertilizer died within two to three months after germination. The number of haustoria and the height growth of the root parasites increased when the parasite was grown with a host and fertilizer.

Either a micro-metabolite or mineral nutrients may be required by the root parasite, *Castilleja coccinea* (16). Though minerals are undoubtedly sequestered by parasitic plants, it is not known which are essential for a parasite's continued existence. Atsatt (2) surmises that potassium and phosphorous are perhaps the key nutrients. Parasitism arose in tropical and subtropical regions, possibly as a adaptive response to mineral-poor soils typical of these regions (9).

Movement of materials through the haustorium is unidirectional, from host to parasite (16). Though the movement of various substances (minerals, carbohydrates, water, hormones, organic acids, etc.) through this structure has been shown (2) the actual materials required are left up to speculation.

Host Specificity

Phanerogamic root parasites in natural plant communities have been mostly ignored until Mann *et. al.* (17) reported on the herbaceous *Seymeria cassioides* (Scrophulariaceae), senna seymeria, killing slash pine (*Pinus elliotii*) in northern Florida. Because of the forestry profession's past lack of concern regarding root parasites, Musselman and Mann (25) studied the ecology and potential host range of nineteen root parasites native to the southeastern U.S. and the potential damage to commercial forest tree species by such parasitism. They discovered actual connections between the root parasite and host tree roots in nearly all of the species tested. None of the 19 root parasites (the majority of which were of the Scrophulariaceae) were host specific.

Host specificity may have important ecological implications, as host species may react differently to the additional demands of the parasite. Most root parasites are nonselective in attaching to a host (e.g., 3, 11, 15, 17, 26, 32, 33, 34); exceptions include *Epifagus virginiana* on *Fagus grandifolia* and *Conopholis americana* on *Quercus*, subgenera *Erythrobalanus*.

Some root parasites have been considered host specific only because they would occur in nature with a certain species, genera, or family. While Pennell was preparing his monograph of the Scrophulariaceae (29) he noticed that the range of *Dasistoma macrophylla* did not agree totally with that of *Aesculus glabra* in Indiana (32). Pennell informed Deam of this inconsistency, convinced that *Aesculus glabra* had to occur wherever *Dasistoma macrophylla* did. Apparently Pennell was persuasive as Deam eventually modified his range map of *A. glabra* to include the range of *D. macrophylla*.

Over 30 years later, the host specificity of *D. macrophylla* on *A. glabra* was disproven as haustoria were found on various other species (32).

Buckleya distichophylla, a rare parasitic shrub endemic to the southern Appalachian mountains, presumably was limited to sites that were dominated by *Tsuga caroliniana*, Carolina hemlock. Piehl (35) however, has demonstrated that *Buckleya* is not host specific to hemlock but rather that it occurs naturally with it because both species have similar site requirements. Musselman and Mann (27) have also shown, in a controlled environment, that *Buckleya* parasitized nineteen different tree host species within five months after germination. Since *Buckleya* and most root parasites can potentially parasitize numerous hosts, these species are most likely restricted in distribution for reasons of site characteristics, such as soil, moisture, exposure, disturbance, etc; or due to a lack of dispersal.

Greenhouse culture of root parasites with potential hosts facilitates the study of haustorial connections. Since haustoria usually are formed on the delicate roots of the parasitic species, Piehl (33) notes that excavating the host and parasite roots virtually alway severs the parasitic root leading to the haustoria. In these circumstances, the haustoria are usually left affixed to the host root and have to be located. A disadvantage of pot culture in establishing host specificity is that this technique only shows what the potential hosts may be (25). It does not account for the competition, the increased microbial activity and the much higher concentration of root exudates more typical of natural plant communities.

Pathogenicity

The demand for host nutrients and water by mistletoe (*Arceuthobium* sp.) induces host stem dieback and eventually death of the host (1). Pathogenicity has also been established for other stem parasites, e.g. dodder, and many root parasites have caused significant losses of agricultural crops, particularly in the tropics. Only *Seymeria cassioides* has been determined as pathogenic to any tree species in the United States. However, other temperate genera, e.g. *Agalinis* and *Orobanche*, are potentially pathogenic (18, 25).

Pathogenicity may be manifested by the parasite inducing a detrimental imbalance of hormones (particularly cytokinins), carbohydrates, inorganic ions (P, K, S, Mg), and nitrogen in the host (9). Host responses include elevated or suppressed levels of respiration, transpiration and photosynthesis; and increased cell division. Perhaps the critical host reaction to parasitism is the deregulation of a sucrose-amino acid cycle in the host (9) which causes a carbohydrate and nitrogen deficiency in the host.

It is essential to study the life history of these parasitic species and to determine which species are pathogenic, since many parasitic plants function as weeds. These opportunistic species are adapted to perturbed environments (25) and respond positively to cultural practices such as site preparation and fertilization (19). Research is needed in this area so that resource managers can make intelligent decisions regarding the treatment of sites occupied by both parasitic and commercial species.

Conclusion

Root parasitism is a form of plant interference given little attention thus far in the literature. However, the effect that a root parasitic species may have on the growth and reproductive potential, and spatial distribution of its associated vegetation, may be important in the dynamics of vegetation change. How the host responds to an additional and continuous moisture and mineral demand depends on many factors within the parasitic species, the hosts, and the environment. The actual loss of growth to

an individual species due to insects or pathogenic organisms is often difficult to quantify. Root parasites may cause no conspicuous pathogenicity in their hosts. However, the loss in host net primary production may be significant due to the demands for its water or nutrients on sites where parasitic plants are common. The assessment of site productivity and the spatial distribution of the vegetation should consider yet another factor, that of root parasitism.

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Sodium Bisulfite in Chloroplast Electron Transport

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Introduction

As shown by Trebst and Schmidt (14) and Schmidt and Trebst (9), sulfite is an intermediate in the photoreduction of sulfate to sulfide by class I chloroplasts. They found this process to be ferredoxin-dependent. Schmidt and Schwenn (8) describe several enzymatic steps involved in this process. Hennies (5) purified the ferredoxin-linked sulfite reductase 125 times. Schwenn et al. (11) found evidence for the participation of both stromal and membrane-bound enzymes in sulfate reduction in chlorophasts. Schwenn and Depka (10) investigated the regulatory influence of adenosine mono- and diphosphates on the first 3 enzymatic steps of sulfate reduction and found that the regulatory step was located at the ATP-sulfurylase reaction site.

Libera *et al.* (6) studied the effect of sodium bisulfite on chloroplast electron transport. They found stimulation of ferricyanide and NADP reduction by bisulfite. Using Tris-washed chloroplasts, they could show electron donation to photosystem II by bisulfite, which was DCMU-sensitive. Asada and Kiso (1) implicate the superoxide anion as the initiator of the DCMU-sensitive sulfite oxidation in illuminated chloroplasts. Univalent oxidation of oxygen is necessary before sulfite can be oxidized.

Several studies dealing with the inhibition of electron transport reactions by SO_2 or sulfide (7,12,13) come to the conclusion that the effect is somewhere between the donor site in Tris-treated chloroplasts and the plastoquinone pool, an effect on the primary donor and the reaction center in PS II not exluded.

In view of the variety of possible bisulfite effects on chloroplasts, this study was undertaken to find out which partial reactions were most severely affected by sodium bisulfite in the sucrose-NaCl chloroplasts. The ultimate aim was to pinpoint the site(s) of action of bisulfite. The inhibition of all PS II reactions by bisulfite has not been reported before.

Materials and Methods

Spinach chloroplasts were isolated from market spinach as previously described (2). Oxygen evolution or uptake were measured with a Clark-type electrode. Reaction rates were recorded with a Sargent-Welch recorder. Reaction components are given in Figure legends.

Tris treatment of chloroplasts to destroy water oxidation was according to Yamashita and Butler (15).

Results and Discussion

The bisulfite stimulation of electron transport reported here is given by lower concentrations (0.5mM, Figure 1) than previously used to demonstrate the ferredoxin-dependent sulfate reduction in chloroplasts (5,6,8,9,10,11,14). Libera *et al.* (6) used 1mM sodium bisulfite to stimulate DCMU-sensitive ferricyanide reduction and 3mM bisulfite to donate electrons to Tris-washed chloroplasts. According to Asada and Kiso (1), the optimum pH for aerobic sulfite oxidation in chloroplasts is 6.8 but it is higher for bisulfite in this study, as shown in Figure 2, where the optimum lies between pH 7 and 7.5

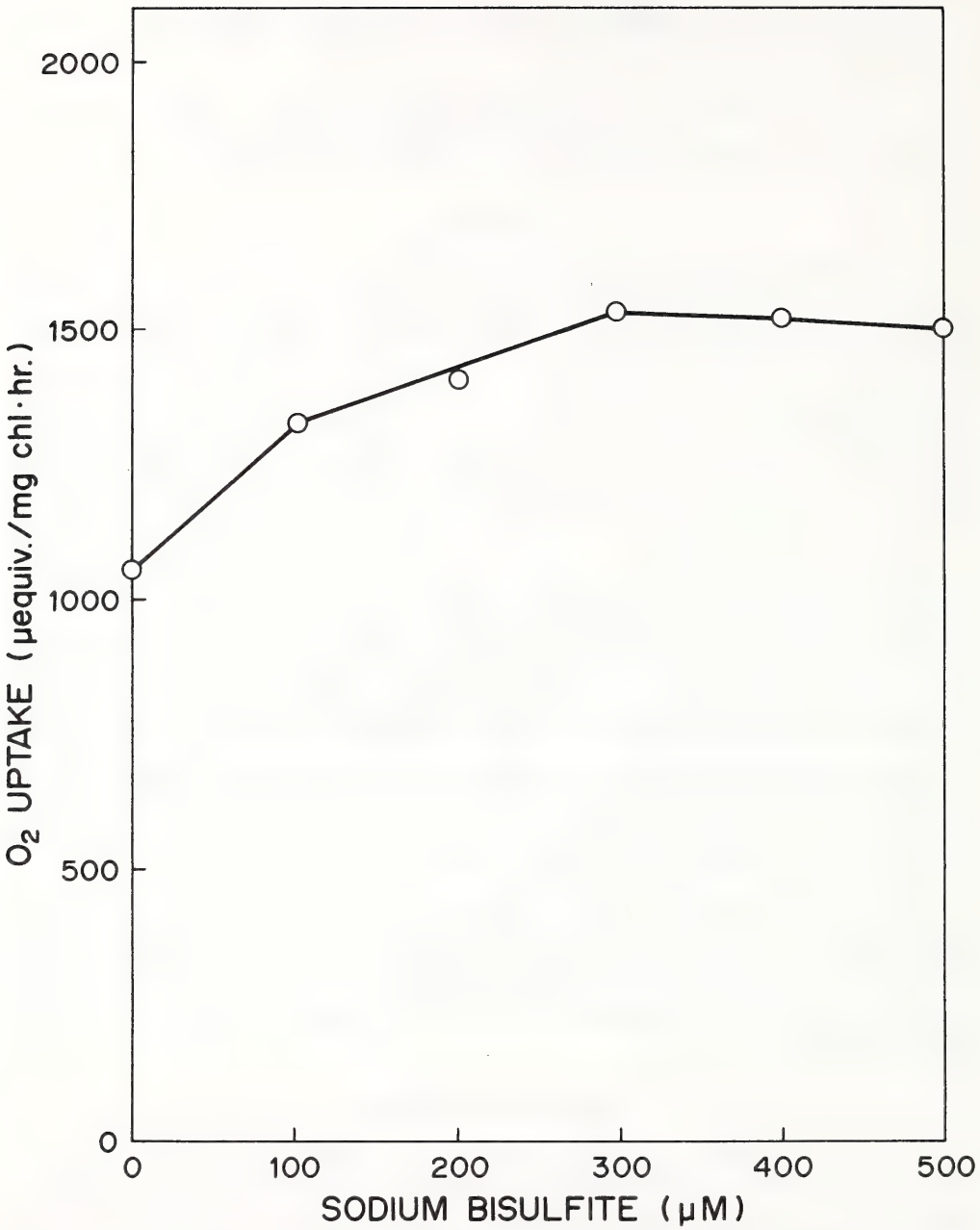

FIGURE 1. *Stimulation of Electron Transport in Spinach Chloroplasts by Various Concentrations of Sodium Bisulfite. The reaction mixture contained chloroplasts (0.05 mg chlorophyll), buffer (25 mM Tris-Mes, pH 7), 0.5 mM Na azide, 0.5 mM methylviologen, and Na bisulfite in concentrations indicated.*

Sodium bisulfite can stimulate the overall electron transport from water to methylviologen up to 50% (Table I) and to about 30% in PS I donor reactions (Table II). Using specific inhibitors, such as DCMU, dibromothymoquinone or polylysine (Table III), which inhibit between the 2 photosystems, the stimulation site can be localized in the region of the plastoquinone pool, i.e. between the dibromothymoquinone and the polylysine inhibition sites. The stimulation sites cannot be located betwen the DCMU and dibromothymoquinone inhibition sites, because the stimulation of electron transport is seen in PS I reactions, where DCMU blocks electron flow from the water oxidation or oxidizing side of PS II.

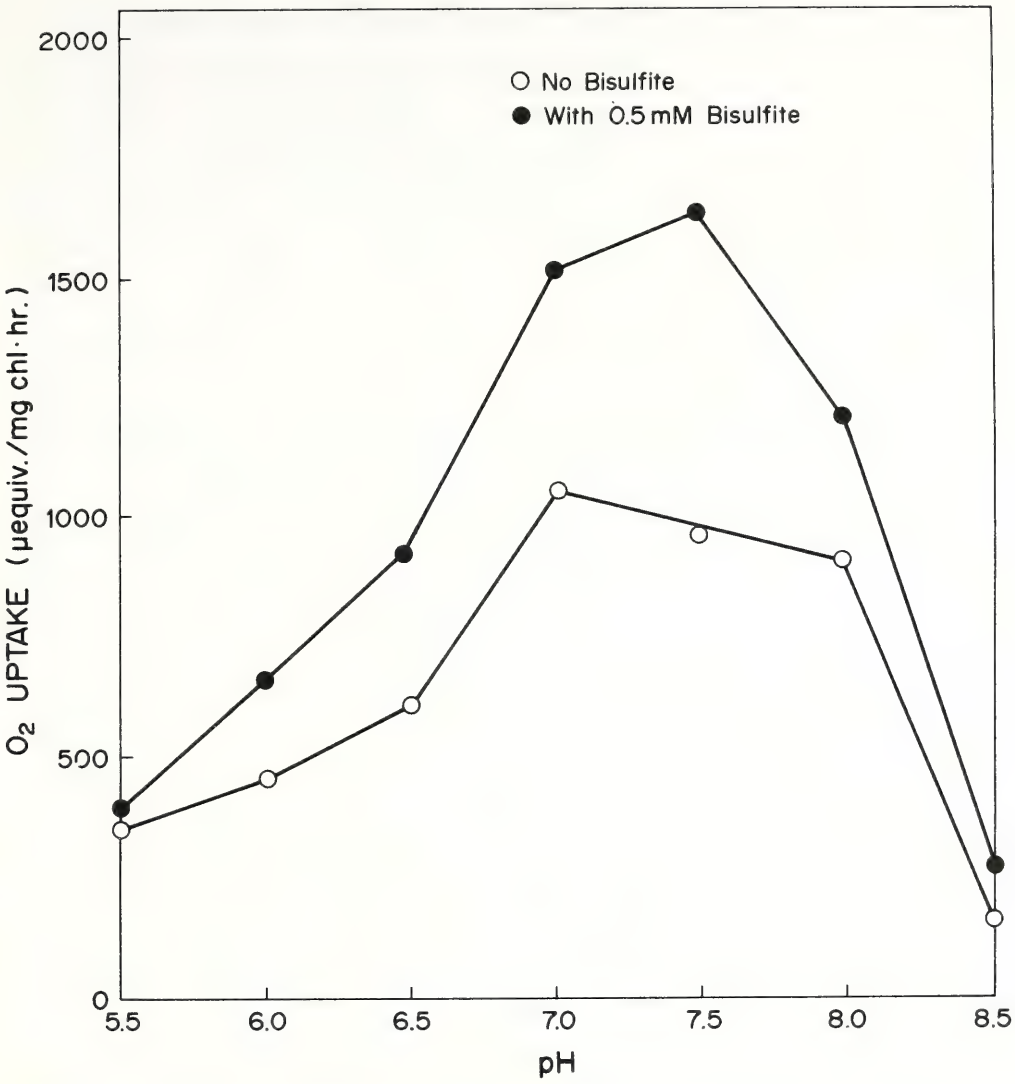

FIGURE 2. *The Effect of pH on Sodium Bisulfite Stimulation of Electron Transport. The reaction mixtures were as in Fig. 1, except the pH of the buffer varied as indicated.*

TABLE I. *Stimulation of Electron Transport by Sodium Bisulfite.*

Reaction and conditions	Bisulfite conc. (mM)	Electron transport rate (μ equiv./mg chl•hr) − bisulfite	+ bisulfite	Stimulation (%)
$H_2O \rightarrow MV$, pH 7	—	671	—	—
$H_2O \rightarrow MV$, pH 7	0.1	—	872	30
$H_2O \rightarrow MV$, pH 7	0.5	—	1009	50
In Tris-treated chloroplasts	—	124	—	—
In Tris-treated chloroplasts	0.5	—	237	91
Without chloroplasts	0.5	0	0	0
Without light	0.5	0	0	0

TABLE II. *Stimulation of Photosystem I Reactions by Sodium Bisulfite.*

Reaction	Bisulfite conc. (mM)	Electron transport rate − bisulfite	Electron transport rate + bisulfite	Stimulation (%)
		(μ equiv./mg chl•hr)		
Ascorbate + DAD → MV, pH 8	0.5	1674	1945	16
Ascorbate + TMPD → MV, pH 8	0.5	767	953	14
Ascorbate + ferrocyanide → MV, pH 8	0.5	2012	2057	2

TABLE III. *The Effect of Inhibitors on Sodium Bisulfite Stimulation of Photosystem I Reactions in Spinach Chloroplasts.*

Reaction	Inhibitor	Conc. (μM)	Electron transport rate − inhibitor	Electron transport rate + inhibitor	Stimulation or inhibition (%)
			(μ equiv./mg chl•hr)		
Ascorbate + DAD → MV	None	—	2345	—	—
Ascorbate + DAD → MV	DBMIB	2.5	—	395	-78[a]
Ascorbate + DAD → MV	None	—	1945	—	—
Ascorbate + DAD → MV	Polylysine[b]	10 μg/ml	—	209	-87
Ascorbate + TMPD → MV	None	—	953	—	—
Ascorbate + TMPD → MV	DBMIB	2.5	—	1009	+32
Ascorbate + TMPD → MV	None	—	861	—	—
Ascorbate + TMPD → MV	Polylysine[b]	10 μg/ml	—	367	-57
Ascorbate + ferrocyanide → MV	None	—	1567	—	—
Ascorbate + ferrocyanide → MV	DBMIB	2.5	—	1274	-19
Ascorbate + ferrocyanide → MV	None	—	2057	—	—
Ascorbate + ferrocyanide → MV	Polylysine[b]	10 μg/ml	—	2125	+6

[a] + indicates stimulation, - inhibition of rate

[b] M.W. 30,000

TABLE IV. *Inhibition of Photosystem II Reactions by Sodium Bisulfite.*

Reaction	Bisulfite conc. (mM)	Electron transport rate − bisulfite	Electron transport rate + bisulfite	Inhibition (%)
		(μ equiv./mg chl•hr)		
H_2O → SM (+DCMU), pH 6	0.10	522	508	3
H_2O → SM (+DCMU), pH 6	0.50	522	428	18
H_2O → SM (+DCMU), pH 8	0.10	256	130	49
H_2O → SM (+DCMU), pH 8	0.50	256	0	100
H_2O → FeCN, pH 6	0.10	444	383	14
H_2O → FeCN, pH 6	0.50	444	428	4
H_2O → FeCN, (+DBMIB), pH 8	0.10	137	62	55
H_2O → FeCN, (+DBMIB), pH 8	0.50	137	0	100
H_2O → DMBQ (+DBMIB), pH 7	0.10	742	727	2
H_2O → DMBQ (+DBMIB), pH 7	0.50	742	259	65

The phenomenon observed in Table IV, which shows the inhibition of PS II partial reactions by sodium bisulfite, especially at higher pH values (pH 7-8), is harder to explain, unless bisulfite acts as a competitive inhibitor of electrons generated in the water oxidation process or at the well-known bicarbonate site on the B protein between the 2 photosystems (4). Another possibility, which cannot be disregarded, is that bisulfite may form addition products with quinones (3). Its inhibition of PS II partial reactions may be consistent with bisulfite modification of plastoquinone A, rendering it incapable of redox reactions. Further studies are necessary to distinquish between these alternatives.

In summary, this study shows that sodium bisulfite may have 2 sites of action in chloroplast electron transport: 1) acting as an inhibitor of several PS II partial reactions and 2) stimulating electron transport at a site between the 2 photosystems. The mechanism of stimulation by sodium bisulfite can be explained on the basis of electron donation to chloroplasts.

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A Compilation of Plant Diseases and Disorders in Indiana—1983

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Introduction

The Plant Diagnostic Clinic in the Department of Botany and Plant Pathology at Purdue University is a service of the Cooperative Extension Service, Purdue Agricultural Experiment Station. The clinic provides a free service for interested persons through the county extension system, for accurate identification of weeds, plant diseases, and plant disorders. This paper is a compilation of plant diseases and disorders which were diagnosed in the clinic from January 1 through Nov.18, 1983. Such a compilation is an invaluable tool in determining the problem areas in which extension personnel need to concentrate. Ultimately, comparisons of yearly disease/disorder compilations could provide additional insight for epidemiological studies in Indiana.

Methods

Plant specimens are submitted to the Plant Diagnostic Clinic from county extension agents, homeowners, growers, nursery operators, consultants, and others. Specimens are diagnosed visually or by culturing the pathogen on selected media. Some virus diseases are diagnosed by the ELISA technique or by the leaf dip technique utilizing the electron microscope. Once a disease or disorder is diagnosed, appropriate control measures are suggested. A summary of the samples diagnosed from January 1 through December 1, 1983 is given in Table 1.

Results

The incidence and severity of infectious diseases were geatly influenced by extremes in environmental conditions in 1983. Excessive rainfall in early spring resulted in an outbreak of a number of foliar infecting diseases on both ornamental and fruit crops. However, reduced rainfall throughout the growing season resulted in an overall decrease in infectious foliar diseases in 1983. Weather and site related problems were common place in Indiana during the 1983 growing season. Tables 2-8 show the host plant, the disease or disorder diagnosed, the pathogen or cause of disorder, and the number of samples received.

Shade and Ornamental Trees

Disease: Excessive rainfall in early spring resulted in the outbreak of a number of foliar infecting diseases. Apple scab was extremely severe (Table 2). By late May susceptible crabapples were showing extensive leaf yellowing and drop. Anthracnose on sycamore, white oak and ash was prevalent in all areas of the state. Diplodia tip blight continued to be the major cause of pine death, and few new reports of pine wood nematode, first reported in 1980 (1), were recorded. Slime flux on oak, elm, maple, and other hardwood trees was very pronounced during July and August. Two cases of bleeding necrosis on sweetgum caused by *Botryosphaeria dothidea* were reported in Tippecanoe County.

Disorders: The combination of drought conditions and extreme heat during July and August resulted in leaf scorch and tree decline being the most commonly recorded disorders (Table 2). Newly planted trees and shrubs were especially hard hit. Soil-line

TABLE 1. *Plant Samples received in the Purdue Plant Diagnostic Clinic Jan 1 through Dec. 1, 1983.*

Plant Specimen	Number of Samples	Disease	Disorder	Chemical	Nutritional
AGRONOMIC					
Corn	80	32	28	11	6
Soybeans	82	58	7	19	4
Small Grain	168	213	23	0	7
Forage Grasses and Legumes	18	20	3	2	1
ORNAMENTAL					
Trees-Shade and Ornamental	304	102	171	17	10
Shrubs and Groundcover	95	33	48	8	5
Flowers	47	32	7	6	5
House plants	32	8	20	0	1
FRUIT					
Tree Fruit	91	38	40	3	0
Small Fruit	64	33	32	6	1
VEGETABLE	108	49	26	17	4
TURFGRASS	37	27	18	0	0
PLANT IDENTIFICATION	196	—	—	—	—
FORWARDED TO ENTOMOLOGY (4%)	85	—	—	—	—
TOTAL	1407	645	423	86	39

1 Problem caused by an infectious disease causing agent, e.g. fungus, bacterium, virus, mycoplasma, nematode.
2 Problem caused by noninfectious environmental stress, e.g. wind, drought, heat, soil compaction.
3 Problem caused by herbicide/pesticide misuse.
4 Problem caused by a nutrient imblance.

TABLE 2. *Shade and Ornamental Trees.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Abies (FIR)		
Miscellaneous Disorders		
Needle Tip Burn	Stress factors	1
Needle Yellowing/Drop	Drought stress	1
Acer (MAPLE)		
Anthracnose	*Gloeosporium apocryptum*	5
Canker	*Nectria* sp.	1
Miscellaneous Disorders		
Scorch	Stress factor(s)	16
Decline	Stress factor(s)	16
Herbicide Injury	Spray drift	4
Dieback	Stress factor(s)	23
Bark Split	Frost injury	1
Trunk/Limb Cankers	Desiccation	1
Leaf Burn	Pesticide misuse	1
Leaf Drop	Stress	2
Tatterleaf	Freeze injury	5
Betula (BIRCH)		
Powdery Mildew	*Phyllactinia* sp.	1
Miscellaneous Disorders		
Scorch	Heat, wind and drought	3
Chlorosis	Nutrient imbalance	1
Decline	Stress factors	1

TABLE 2.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Carya (HICKORY)		
Downy Spot	*Microstroma juglandis*	1
Castanea (CHESTNUT)		
Heart Rot	unidentified	1
Leaf Blight	unidentified	1
Miscellaneous Disorder		
Leaf Curl	Herbicide drift	1
Catalpa (CATALPA)		
Miscellaneous Disorder		
Leaf Scorch	*Stress factor(s)*	*1*
Cercis (RED BUD)		
Wilt	*Verticillium albo-atrum*	2
Miscellaneous Disorders		
Leaf Scorch	Heat, wind, and drought	1
Leaf Burn	Pesticide misuse	1
Cornus (DOGWOOD)		
Miscellaneous Disorders		
Dieback	Site stress	2
Leaf Purpling	Cold	1
Leaf Scorch	Heat, wind, drought	2
Cotinus (SMOKETREE)		
Anthracnose	*Gloeosporium* sp.	1
Miscellaneous Disorder		
Curled Leaves	Herbicide misuse	1
Elaeagnus (RUSSIAN OLIVE)		
Miscellaneous Disorders		
Sapling Storage Molds	Poor ventillation	1
Tree Decline	Root stress	2
Fagus (BEECH)		
Miscellaneous Disorder		
Decline	Stress factor(s)	1
Fraxinus (ASH)		
Anthracnose	*Gloeosporium aridum*	9
Miscellaneous Disorders		
Leaf Scorch	Heat, wind, and drought	2
Tatterleaf	Freeze injury	1
Leaf Drop	Stress factor(s)	1
Gleditsia (HONEY LOCUST)		
Miscellaneous Disorder		
Tatterleaf	Freeze injury	1
Juglans (WALNUT)		
Anthracnose	*Gnomonia leptostyla*	2
Juniperus virginiana (RED CEDAR)		
Twig Blight	*Phomopsis juniperovora*	4
Cedar-Apple Rust	*Gymnosporangium juniperi-virginianae*	1
Miscellaneous Disorder		
Chlorosis	Stress factors	1
Liquidambar (SWEET GUM)		
Bleeding Necrosis	*Botryosphaeria dothidea*	2
Miscellaneous Disorder		
Decline	Stress factor(s)	1
Liriodendron (TULIP TREE)		
Powdery Mildew	*Erysiphe polygoni*	1

TABLE 2.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Miscellaneous Disorders		
Leaf Yellowing/Spotting	Site Stress	8
Leaf Scorch	Heat, wind, drought	2
Limb Dieback	Stress factor(s)	2
Magnolia (MAGNOLIA)		
Miscellaneous Disorder		
Dieback	Winter Injury	1
Malus (CRABAPPLE)		
Scab	*Venturia inaequalis*	15
Powdery Mildew	Unidentified	1
Miscellaneous Disorders		
Leaf Scorch	Stress factor(s)	1
Leaf Curl	Herbicide drift	2
Picea (SPRUCE)		
Canker	*Cytospora kunzei*	2
Needlecast	*Rhizosphaera kalkoffii*	4
Miscellaneous Disorders		
Chlorosis	Poor site location	5
Needle Loss	Stress factor(s)	6
Needle Browning	Site stress	10
Leaf Mottle	Nutritional imbalance	1
Branch Dieback	Herbicide misuse	1
Pinus (PINE)		
Tip Blight	*Diplodia pinea*	3
Needle Blight	*Dothistroma pini*	1
Needle Cast	*Lophodermium pinastri*	4
Needle Rust	*Coleosporium* sp.	1
Western Gall Rust	*Endocronartium harknessii*	1
Sooty Mold	*Fumago vagans*	2
Miscellaneous Disorders		
Decline	Poor drainage, site-stress	16
Winter Damage	Desiccation	10
Chlorotic Needles	Site stress	6
Dieback	Transplant shock	2
Needle Tip Burn	Environmental stress	3
Chlorotic Needles	Herbicide damage	2
Needle Drop	Normal	2
Dieback	Shovel Root (Poor planting)	1
Platanus (SYCAMORE)		
Anthracnose	*Gnomonia veneta*	2
Miscellaneous Disorder		
Leaf Scorch	Environmental stress	1
Plantanus acerifolia (LONDON PLANE)		
Anthracnose	*Gnomonia plantani*	1
Twig Canker	Unidentified	1
Populus (POPLAR)		
Canker	*Cytospora*	2
Miscellaneous Disorders		
Dieback	Site stress	1
Dieback	Site stress/cold	1
Prunus (PURPLE LEAF PLUM)		
Miscellaneous Disorder		
Decline	Stress	1
Prunus (ORIENTAL CHERRY)		
Miscellaneous Disorder		
Decline	Root stress	1

TABLE 2.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Quercus (OAK)		
Canker	*Dothiorella*	1
Leaf Spot	*Actinopelte dryina*	5
Anthracnose	*Gnomonia quercina*	9
Blisterleaf	*Taphrina caerulescens*	3
Oak Wilt	*Chalara quercinum*	1
Miscellaneous Disorders		
Chlorosis	Nuturitional Deficiency	7
Leaf Curl	Herbicide	1
Leaf Scorch	Environmental stress	2
Tatterleaf	Unknown	5
Decline	Site	3
Salix (WILLOW)		
Canker	*Cytospora* sp.	2
Miscellaneous Disorder		
Dieback	Stress	1
Sorbus (MOUNTAIN ASH)		
Canker	Sunscald-canker complex	1
Tsuga (HEMLOCK)		
Miscellaneous Disorders		
Dieback	Drought	2
Curled Leaves	Herbicide	1
Ulmus (ELM)		
Dutch Elm Disease	*Ceratocystis ulmi*	3
Black Leaf Spot	*Gnomonia ulmea*	2
Anthracnose	*Gloeosproium inconspicuum*	1

heat cankers occurred in many new plantings of white pine. A previously unreported disorder occurred on many of the white oak in northern Indiana. Newly developed leaves had a 'tattered' appearance with the leaf blade missing to the main and lateral veins. The leaf malformation occurred in all size trees from seedlings to timber size trees. Late freeze injury was considered as a possible cause but did not explain the entire symptom picture. Drought related dieback of hemlock occurred in many areas of the state in late summer.

Ornamentals

Diseases: Black spot of rose, juniper tip blight, and powdery mildew of various shrubs were frequently reported during spring. Botrytis blight was common on peonies, tulips, roses, and geraniums early in the growing season, again primarily due to the wet weather conditions. Dieback of yews caused by *Phytophthora* spp. was common in a number of nurseries throughout the state (Table 3).

Disorders: Dieback of burning bush was extensive in many locations. The cause of dieback was associated with an early spring warm up followed by freezing weather. Scorch and dieback were of frequent occurrence during the summer months, especially in new plantings (Table 3). As in previous years (1, 2, 3, 4, 5) houseplant problems were primarily related to poor cultural conditions, e.g. overwatering, salt build-up, low humidity, etc.

TABLE 3. *Ornamentals—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Aglaonema (CHINESE EVERGREEN)		
Leaf Spot	Bacterial	1
Agrostemma (CORNFLOWER)		
Miscellaneous Disorder		
Curled Leaves	Herbicide misuse	1
Ajuga (BUGLE WEED)		
Leaf Curl	Herbicide misuse	1
Aloe (ALOE)		
Dieback	Unidentified root rot	1
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Althaea (HOLLYHOCK)		
Rust	*Puccinia malvacearum*	1
Araucaria (NORFOLK ISLAND PINE)		
Miscellaneous Disorder		
Dieback	Improper cultural care	1
Asarum (GINGER)		
Root Rot	*Rhizoctonia solani*	1
Crown Rot	*Sclerotinia sclerotiorum*	1
Aspidastra (CAST IRON PLANT)		
Miscellaneous Disorder		
Scorch	Improper cultural care	1
Begonia (BEGONIA)		
Miscellaneous Disorder		
Leaf Scorch	Chemical misuse	1
Bellis (ENGLISH DAISY)		
Root Rot	*Rhizoctonia solani*	1
Berberis (BARBERRY)		
Root Rot	*Phytophthora* sp.	1
Miscellaneous Disorders		
Dieback	Environmental stress factor(s)	1
Leaf Curl	Herbicide misuse	1
Boxus (BOXWOOD)		
Miscellaneous Disorder		
Chlorosis	Nutrient imbalance	1
Chrysanthemum (CHRYSANTHEMUM)		
Leaf Spot	*Alternaria* sp.	1
Stem Canker	*Erwinia chrysanthemi*	1
Stem/Crown Rot	*Fusarium* sp.	2
Miscellaneous Disorder		
Chlorosis	Fertilizer burn	1
Citrus (ORANGE TREE)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Cosmos (COSMOS)		
Miscellaneous Disorder		
Leaf Spot	Environmental stress	1
Cotoneaster (COTONEASTER)		
Miscellaneous Disorder		
Dieback	Root decline	1
Crassula (JADE PLANT)		
Leaf Blight	*Botrytis* sp.	1
Crateagus (HAWTHORN)		
Rust	*Gymnosporangium clavipes*	4
Fireblight	*Erwinia amylovora*	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Miscellaneous Disorder		
Dieback	Environmental stress	1
Dahlia (DAHLIA)		
Tuber Rot	*Fusarium* sp.	1
Tuber Rot	*Penicillim* sp.	1
Euonymous (BURNING BUSH)		
Miscellaneous Disorders		
Leaf Scorch	Environmental stess	3
Chlorosis	Nutritional imbalance	2
Dieback	Stress factor(s)	2
Euphorbia (POINSETTIA)		
Root Rot	*Phythium* sp.	1
Stem Rot	*Fusarium* sp.	1
Top Rot	*Botrytis* sp.	1
Fatsia (CASTOR OIL PLANT)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Ficus (WEEPING FIG)		
Miscellaneous Disorders		
Leaf Spot	Improper cultural care	1
Leaf Spot	Pesticide burn	1
Ficus (RUBBER PLANT)		
Anthracnose	*Glomerella cingulata*	1
Miscellaneous Disorder		
Leaf Drop	Improper cultural care	1
Forsythia (FORSYTHIA)		
Miscellaneous Disorder		
Stem/Leaf Twist	Herbicide misuse	1
Frangipani (PLUMERIA)		
Stem Rot	*Fusarium* sp.	1
Geranium (GERANIUM)		
Root Rot	*Phytophthora* sp.	1
Gladiolus (GLADIOLUS)		
White Break Mosaic	White Break Mosaic Virus	1
Hedera (ENGLISH IVY)		
Anthracnose	*Colletotrichum* sp.	2
Bacterial Leaf Spot	*Xanthomonas hederae*	2
Hemerocallis (DAYLILLY)		
Anthracnose Leaf Spot	*Colletotrichum* sp.	1
Hoya (WAXPLANT)		
Miscellaneous Disorder		
Chlorosis	Stress	1
Ilex (HOLLY)		
Root Rot	*Phytophthora* sp.	1
Miscellaneous Disorders		
Leaf Scorch	Ice scald	3
Oedema	Stress	1
Impatiens (IMPATIENS)		
Root Rot	*Rhizoctonia solani*	1
Miscellaneous Disorder		
Leaf Spot	Environmental stress	1
Iris (IRIS)		
Miscellaneous Disorder		
Leaf Spot	Frost	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Juniperus (JUNIPER)		
Twig Blight	*Phomopsis juniperovora*	3
Miscellaneouse Disorders		
Dieback	Environmental/site stress	4
Chlorosis	Stress factor(s)	1
Needle Burn	Oil damage	1
Lonicera (HONEYSUCKLE)		
Leaf Blight	*Herpobasidium deformans*	2
Anthracnose	*Colletotrichum* sp.	1
Miscellaneous Disorder		
Scorch	Stress factor(s)	1
Maranta (PRAYER PLANT)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Monstera (SWISS CHEESE PLANT)		
Anthracnose	*Colletotrichum* sp.	1
Miscellaneous Disorder		
Leaf Scorch	Improper cultural care	1
Opuntia (CACTUS)		
Soft Rot	Bacterial	1
Leaf Spot	*Phyllosticta concava*	1
Orchid (ORCHID)		
Leaf Spot	Cymbidium virus	2
Pachysandra (JAPANESE SPURGE)		
Leaf/Stem Blight	*Volutella pachysandrae*	5
Paeonia (PEONY)		
Leaf Spot	*Cladosporium paeoniae*	1
Pandanas (SCREW PINE)		
Miscellaneous Disorder		
Trunk Damage	Physical damage	1
Parthenocissus (BOSTON IVY)		
Black Rot	*Guignardia bidwelli*	2
Pelargonium (GERANIUM)		
Blackleg	*Pythium* sp.	3
Stem Rot	*Xanthomonas pelargonii*	1
Miscellaneous Disorder		
Chlorosis	Improper cultural care	2
Oedema	Over watering/shade	2
Pteridum (FERN)		
Miscellaneous Disorder		
Brown Leaf Spots	Natural spores	1
Pyracantha (FIRETHORN)		
Scab	*Fusicladium pyracanthae*	1
Miscellaneous Disorder		
Dieback	Winter injury	1
Rhododendron (AZALEA)		
Leaf Gall	*Exobasidium vaccinii*	1
Miscellaneous Disorder		
Chlorosis	Nutrient imbalance	1
Dieback	Environmental/site stress	3
Rosa (ROSE)		
Black Spot	*Diplocarpon rosae*	2
Petal Blight	*Botrytis* sp.	1
Canker	*Coniothyrium wernsdorffiae*	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Miscellaneous Disorder		
Leaf Curl	Herbicide misuse	1
Saintpaulia (AFRICAN VIOLET)		
Miscellaneous Disorders		
Root Rot	Hi soil nitrate	1
Leaf Rot	Rim rot	1
Sansevieria (SNAKE PLANT)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Schefflera (UMBRELLA TREE)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Scindapsus (POTHOS)		
Miscellaneous Disorder		
Leaf Spot	Sunburn	1
Spathiphyllum (PEACE LILLY)		
Miscellaneous Disorder		
Leaf Scorch	Environmental stress	1
Streptocarpus (CAPE PRIMROSE)		
Miscellaneous Disorder		
Leaf Spot	Improper cultural care	1
Syringa (LILAC)		
Powdery Mildew	*Microsphaera alni*	1
Miscellaneous Disorder		
Leaf Scorch	Site stress	1
Tagetes (MARIGOLD)		
Miscellaneous Disorder		
Leaf Curl	Herbicide drift	1
Tanacetum (TANSY)		
Root Rot	*Phytophthora* sp.	1
Taxus (YEW)		
Yew Dieback	Poor site location/root rot complex	6
Miscellaneous Disorders		
Needle Browing	Winter Desiccation	4
Tip Dieback	Freeze injury	2
Needle Curl	Herbicide drift	4
Chlorosis	Site stress	3
Needle burn	Sun scorch	1
Thuja (ARBORVITAE)		
Tip Dieback	*Pestalotia funerea*	2
Miscellaneous Disorders		
Needle Bronzing	Environmental stress	6
Tip Dieback	Poor root establishment	3
Dieback	Winter desiccation	3
Tulipa (TULIP)		
Flower Blight	*Botrytis* sp.	1
Viburnum (VIBURNUM)		
Powdery Mildew	*Microsphaera alni*	1
Vinca (PERIWINKLE)		
Stem Blight	*Phoma exigua*	3
Miscellaneous Disorders		
Dieback	Cold injury	1
Dodder	*Cuscuta indecora*	1
Viola (PANSY)		
Leaf Blight	*Botrytis* sp.	1

TABLE 3.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Wistaria (WISTERIA)		
Miscellaneous Disorder		
Leaf Scorch	Stress	1
Zinnia (ZINNIA)		
Miscellaneous Disorder		
Leaf Curl	Herbicide drift	1
Zygocactus (CHRISTMAS CACTUS)		
Stunt Nematode	*Tylenchorhynchus* sp.	1

Tree Fruits

Diseases: Apple scab was epidemic in various orchards in the state due to the extreme wet spring. Peach leaf curl was prevalent early in the year due to the delayed wet spring conditions (Table 4). Bacterial spot of peach, nectarine and plum was widespread throughout the state. Powdery mildew was observed more frequently than in previous years. The increase in powdery mildew was attributed to the extreme mild winter. Fireblight, for a change, was not of widespread occurrence.

Disorders: Late freezes caused extensive losses to both the peach crop and certain apple varieties. Many apple cultivars showed extensive tattering of primary leaves due to the late spring freezes which occurred. A number of cases of individual tree death were related to a combination of a weakened tree and drought conditions.

Small Fruits

Diseases: The predominant diseases on small fruits were black rot of grape, which was epidemic on non-sprayed vineyards in southern Indiana, and strawberry leaf and stem diseases, in particular, strawberry leaf scorch (Table 5).

Disorders: Drought related problems occurred on a number of small fruits, especialy brambles, late in the year. Poor fruit formation and/or malformed fruit were the major complaints.

Turfgrass

Diseases: As in previous years (1,2,3,4) the extended wet weather during the spring was conducive to considerable Helminthosporium leaf spot and melting out (Table 6). This disease complex was an additional stress on grass plants during the hot, dry summer which resulted in many turf areas being completely killed. Cool weather brown patch caused by *Rhizoctonia solani* was observed in many turf areas in spring. For the first time in several years, Fusarium blight was not a major turf problem. It is felt that the hot, dry weather rapidly killed plants and probably precluded the diagnosis of Fusarium blight where it was present. Pythium blight and Rhizoctonia brown patch on bentgrass were troublesome during the summer, while dollar spot was relatively light. Ophiobolus patch was suspected on annual bluegrass. Severe nematode problems were identified in the bentgrass greens of a central Indiana golf course.

Disorders: Improper cultural care, involving thatch build-up and environmental stress were common noninfectious problems.

TABLE 4. *Fruit Trees—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Malus sylvestris (APPLE)		
Scab	*Venturia inaequalis*	9
Cedar-Apple Rust	*Gymnosporangium juniperi-virginianae*	3
Fireblight	*Erwinia amylovora*	3
Apple Blotch	*Phyllosticta* sp.	1
Stem Canker	unidentified	1
Frog-Eye Leaf Spot	*Phyllosticta* sp.	1
Bacterial Spot	*Pseudomonas syringae*	1
Miscellaneous Disorders		
Bud Death	Cold injury	1
Chemical Injury	Improper use	2
Leaf Scorch	Heat, wind and drought	4
Trunk Canker	Incompatible Root Stock	1
Leaf Spot/Curl	Frost damage	3
Ripped Lower Leaf Epidermis	Cold	1
Twig Cankers	Freeze injury	1
Stunted Fruit	Tree decline	1
Leaf Curl	Desiccation	1
Leaf Drop	Stress	1
Rotted Fruit	Heat scald	1
Water Core	Heat	1
Prunus americana (PLUM)		
Black Knot	*Dibotryon morbosum*	1
Plum Pockets	*Taphrina deformans*	1
Prunis avium (CHERRY)		
Miscellaneous Disorders		
Root Rot	Wet site location	5
Dieback	Stress factor(s)	3
Leaf Scorch	Stress	2
Leaf Drop	Heat, wind, and drought	2
Prunis persica (PEACH)		
Peach Leaf Curl	*Taphrina deformans*	5
Bacterial Spot	*Xanthomonas pruni*	5
Scab	*Cladosporium carpophilum*	3
Miscellaneous Disorders		
Herbicide damage	Spray drift	1
Chlorotic Leaves	Stress	1
Leaf Scorch	Frost	1
Prunis persica var. *nectarina* (NECTARINE)		
Leaf Curl	*Taphrina deformans*	1
Pyrus communis (PEAR)		
Scab	*Venturia pyrina*	1
Miscellaneous Disorders		
Leaf Scorch	Heat, wind, and drought	10
Leaf spot	Stress	1

Vegetables

Diseases: Cool, wet weather in the early part of the growing season favored root diseases such as Rhizoctonia root rot of beans, black leg of crucifers and Sclerotinia stem rot of fresh market tomatoes. These diseases were present to some extent in most fields. However, fields severely affected by these root diseases were not common.

TABLE 5. *Small Fruits—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Fragaria grandiflora (STRAWBERRY)		
Black Root Rot	Fungal complex	8
Leaf Spot	*Mycosphaerella fragariae*	1
Leaf Scorch	*Diplicarpon earliana*	1
Leaf Blight	*Dendrophama obscurans*	1
Gray Mold Rot	*Botrytis cinerea*	1
Root Knot Nematode	*Meloidogyne hapla*	1
Miscellaneous Disorders		
Root Rot	Cold injury/poor site	13
Herbicide Injury	Drift	2
Dieback	Poor root establishment	2
Leaf/Fruit Deformed	Chemical misuse	1
Ribes (GOOSEBERRY)		
Miscellaneous Disorder		
Leaf Scorch	Stress	1
Rubus (RASPBERRY)		
Anthracnose	*Elsinoe veneta*	3
Spur Blight	*Didymella applanata*1	
Cane Gall	*Agrobacterium rubi*	1
Fruit Rot	*Botrytis cinerea*	1
Miscellaneous Disorders		
Dieback	Cold injury	7
Leaf Scorch	Heat, wind, and drought	4
Vaccinium (BLUEBERRY)		
Miscellaneous Disorders		
Dieback	Transplant shock	1
Leaf spot	Desiccation	1
Vitis (GRAPE)		
Crown Gall	*Agrobacterium tumefaciens*	1
Stem Canker	Unidentified fungus	3
Black Rot	*Guignardia bidwelli*	5
Miscellaneous Disorders		
Herbicide Injury	Spray drift	3
Leaf Spot	Environmental stress	1
Small Fruit	Heat/drought stress	1
Uneven Fruit Ripening	Heat/drought stress	1

Damping-off was not widespread on melon seedlings, presumably because of improved cold frame management practice by melon growers. A Rhizoctonia-induced damping-off was a significant problem for many fresh market pepper producers in northwest Indiana (Table 7). Pepper growers were also plagued by Phytophthora blight, especially where rotations out of Solanaceous crops were short and where disease was a problem in the past.

Hydroponic tomato growers suffered losses due to infection by *Colletotrichum coccodes*, a root rotting fungus. Management practices which tend to injure tomato stems slightly above the level of the nutrient solution were found to predispose plants to infection. The fungus gained entrance via the wounds and slowly colonized plants resulting in wilting and death of infected plants.

The foliar pathogens which often cause serious damage to maturing vegetable

TABLE 6. *Turf—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Poa pratensis (BLUEGRASS)		
Leaf Spot	*Helminthosporium* sp.	10
Fusarium Blight	*Fusarium roseum* complex	5
Red Thread	*Corticium fuciforme*	2
Brown Patch	*Rhizoctonia solani*	2
Slime Mold	*Physarum cinereum*	1
Miscellaneous Disorders		
Dieback	Drought stress	4
Excessive Thatch	Improper cultural care	12
Agrostis sp. (BENTGRASS)		
Stunt Nematode	*Tylenchorhynchus* sp.	2
C-15 Decline	Unknown	1
Brown Patch	*Rhizoctonia solani*	1

TABLE 7. *Vegetables—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Allium cepa (ONION)		
Leaf Rust	*Puccinia asparagi*	1
Brassica oleracea var. *capitata* (CABBAGE)		
Black Rot	*Xanthonomas campestris*	*2*
Wirestem	*Rhizoctonia solani*	2
Miscellaneous Disorder		
Chlorotic	Nutrient imbalance	1
Brassica rapa (TURNIP)		
Storage Rot	Unidentified bacteria	1
Brasica ruvo (BROCCOLI)		
Wirestem	*Rhizoctonia solani*	1
Capsicum frutescens (PEPPER)		
Stem Canker	*Rhizoctonia solani*	3
Miscellaneous Disorder		
Sunscald	Poor leaf coverage	1
Citrullus vulgaris (WATERMELON)		
Miscellaneous Disorder		
Leaf Spot	Air pollution	4
Cucumis melo (CANTALOPE)		
Bacterial Wilt	*Erwinia tracheiphila*	3
Fusarium Wilt	*Fusarium oxysporum*	1
Leaf Spot	*Alternaria cucumerina*	3
Miscellaneous Disorders		
Leaf Spot	Air pollution	*3*
Leaf Scorch	Desiccation	*1*
Cucumis sativus (CUCUMBER)		
Baterial Wilt	*Erwinia tracheiphila*	7
Miscellaneous Disorder		
Leaf Spot	Paraquat drift	1
Cucurbita moschata (PUMPKIN)		
Miscellaneous Disorder		
Swollen Stem	Unknown cause	1
Cucurbita pepo (ZUCCHINI)		
Miscellaneous Disorders		
Leaf Scorch	Heat, wind	1
Leaf Spot	Paraquat drift	1

TABLE 7.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Ipomoea batatas (SWEET POTATO)		
Storage Rot	*Botrytis* sp.	1
Lactuca sativa var. *crispa* (LEAF LETTUCE)		
Miscellaneous Disorders		
Root Burn (Hydroponics)	Nutrien imbalance	2
Tip Dieback (Greenhouse)	Cultural stress	1
Lycopersicon esculentum (TOMATO)		
Septoria Leaf Spot	*Septroia lycopersici*	2
Early Blight	*Alternaria solani*	1
Black Dot Root Rot (Hydroponics)	*Colletotrichum coccodes*	2
Pythium Root Rot (Hydroponics)	*Pythium* spp.	2
Pythium Damping Off	*Pythium* spp.	1
Southern Wilt	*Sclerotium rolfsii*	1
Bacterial Spot	*Xanthomonas vesicatoria*	1
Bacterial Canker	*Corynebacterium michiganensis*	2
Fusarium Canker (Hydroponics)	*Fusarium* spp.	2
Fusarium Canker (Greenhouse)	*Fusarium* spp.	1
Root Knot Nematode	*Meloidigyne hapla*	1
Miscellaneous Disorders		
Blotchy Ripening	Environmental stress	4
Leaf Chlorosis	Environmental stress	1
Walnut Wilt	Juglone toxin	2
Dieback	Environmental stress	1
Stem Canker (Hydroponics)	Improper placement in tube	3
Leaf Spot	Wind, heat	3
Leaf Curl	Herbicide drift	2
Leaf Burn	Improper pesticide use	2
Catface	Environmental stress	3
Blossom End Rot	Environmental stress	2
Phaseolus vulgaris (SNAP BEAN)		
Root Rot	*Rhizoctonia solani*	2
Root Rot	*Fusarium* sp.	1
Stem Rot	*Sclerotinia sclerotiorum*	1
Mosaic	Mosaic virus	2
Miscellaneous Disorders		
Leaf Spot	Paraquat drift	1
Leaf Curl	Growth regulator injury	1
Leaf Burn	Heat, wind, drought	7
Rheum spp. (RHUBARB)		
Leaf Spot	*Aschochyta* spp.	1
Miscellaneous Disorder		
Crown Rot	Poor site location	1
Solanum tuberosum (POTATO)		
Tuber Rot	*Fusarium* sp.	3
Common Scab	*Streptomyces scabies*	1
Soft Rot	*Erwinia* spp.	2
Late Blight (Tuber)	*Phytophthora infestans*	1
Miscellaneous Disorders		
Leaf Curl	Herbicide drift	1
Tuber Spot	Improper storage	1
Zea Mays var. *saccharata* (SWEET CORN)		
Miscellaneous Disorders		
Leaf Scorch	Environmental stress	1
Leaf Spot	Paraquat drift	1
Leaf Flecking	Genetic	1

crops failed to present problems. The hot, dry weather which prevailed throughout the summer prevented serious epidemics from occuring.

Disorders: Non-infectious diseases caused significant problems among crucifers and cucurbits. A bacterial soft rot of broccoli heads developed where crops were side-dressed with excess nitrogen fertilizer. Two side-dress applications of 25 lbs N after broadcast application of 100 lbs N resulted in less head rot than side-dress applications of 50 lbs N.

Molybdenum deficiency, characterized by marginal chlorosis and necrosis occurred among muskmelon crops planted in acid (pH 4.4-5.2) soils. Remarkable recovery was achieved in several days after vines were treated with 2 oz of sodium molybdate in 100 gal water per acre. Muskmelons in sandy, acid (pH 4.5-5.5) soils suffered from magnesium deficiency where pH was not corrected by application of dolomitic lime.

The most significant revelation of 1983 was that ambient air pollution (ozone and sulfur dioxide) caused serious damage to watermelons and muskmelons (Table 7). Symptons of air pollution damage are not unlike those produced by downy mildew infection in its early stages. It is believed that air pollution had been adversely affecting the melon crops in southwest Indiana for at least several years.

Agronomic Crops

Diseases-Wheat: A mild fall and winter followed by a cool wet spring lead to development of several wheat diseases. However, the dry weather that started in June, except in southern Indiana checked disease development. Yield losses in the northern two-thirds of the state were estimated to be approximately 7 bu/A. In the southern third of Indiana, where rainfall continued until the end of June, yield losses were estimated to be approximately 30 bu/A. The barley yellow dwarf virus was found throughout the state (Table 8). This was the most severe outbreak of barley yellow dwarf in several years. Fall infection by the virus was most prevalent in the southern half of the state. The aphid vectors of the virus were suspected of overwintering in some fields in the far southern part of the state. Wheat spindle streak was observed in the majority of fields throughout the state (Table 8). However, yield losses due to this virus disease are estimated to be approximately 3 bu/A in most fields. Septoria leaf blotch, Septoria glume blotch, powdery mildew and head scab were commonly found diseases throughout the state, but, of course were more severe in the southern third. Strip rust caused by *Puccinia striiformis* was found in trace amounts in several fields in the southeast, central and northwestern parts of the state.

Diseases-Corn: Leaf blights were at their lowest levels in many years due to the hot, dry summer. Common smut was prevalent throughout the state, and the most severe in several years. Yield losses from this disease were estimated to be approximately 1 to 2 bu/A. Due to severe temperature and moisture stress, stalk rots and ear rots were prevalent throughout the state and most severe in the more severely drought stressed areas. Fusarium ear rot was the most commonly encountered ear rot. Based on an ear rot survey *Aspergillus flavus* invasion of ears was found in approximately 12% of fields scattered throughout the state (Table 8). The most prevalent invasion occurred in the most severely drought stressed areas, and primarily the western half of the state. Aflatoxin analysis of 502 fields randomly selected from 66 counties scattered over the state revealed that approximately 7% of the field samples contained this mycotoxin. Concentrations of aflatoxin ranged from 5 ppb (parts per billion) to 500 ppb with an average concentration of approximately 85 pp. This was the most severe record of aflatoxin in Indiana.

Diseases-Soybean: *Phytophthora* root rot of soybeans was more severe and widespread than usual due to heavy rainfall in May (Table 8). *Rhizoctonia* root rot was also com-

monly found throughout the state. Brown spot and downy mildew were commonly found foliar disease of soybeans, but yield losses from these foliar diseases were in-

TABLE 8. *Agronomic Crops—Diseases and Disorders.*

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Triticum (WHEAT)		
Wheat Spindle Streak	Wheat Spindle Streak Virus	97
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	43
Septoria Leaf Blotch	*Septoria tritici*	54
Powdery Mildew	*Erysiphe graminis*	6
Head Mold	*Cladosporium* sp.	4
Tan Spot	*Helminthosporium sativum*	2
Stripe Rust	*Puccinia striiformis*	1
Fusarium Root Rot	*Fusarium* sp.	1
Miscellaneous Disorders		
Inhibited Growth	Soybean residue	1
Chlorosis	Nutrient imbalance	1
Stunted Growth	Heaved out of ground	6
Leaf Mottling	Environmental stress	8
Leaf Purpling	Environmental stress	11
Root Burn	Improper fertilizer application	1
Avena (OAT)		
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	2
Hordeum (BARLEY)		
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	2
Leaf Scald	*Rhynchosporium secalis*	1
Zea (DENT CORN)		
Pythium Seedling Blight	*Pythium aphanidermatum*	6
Stewart's Blight	*Erwinia stewartii*	4
Lesion Nematode	*Pratylenchus penetrans*	4
Lance Nematode	*Hoplolaimus galeatus*	1
Ear Rots (See Below)		
Fusarium Kernel Rot	*Gibberella zeae*	2
Fusarium Kernel Rot	*Fusarium moniliforme*	2
Kernel Rot	*Diplodia maydis*	1
Kernel Rot	*Pennicillium* spp.	1
Kernel Rot	*Helminthosporium carbonum*	1
Kernel Rot	*Aspergillus flavus*	30
Stalk Rot (See Below)		
Fusraium Stalk Rot	*Fusarium moniliforme*	1
Anthracnose Stalk Rot	*Colletotrichum graminicola*	1
Miscellaneous Disorders		
Curled Brace Roots	Heat stress	3
Curled Brace Roots	Herbicide damage	1
Tall Corn/Short Corn	Environmental factors	4
Purple Leaves	Environmental stress	1
Storage Rot	Poor ventillation	1
Leaf Curl	Herbicide injury	1
Seed Rot	Improper fertilizer application	1
Root Burn	Improper fertilizer application	1
Brown Leaf Streaks	Sand blasting	3
Leaf Scorch	Heat, drought	10
White Leaves	Boron toxicity	1
Stubby Roots	Herbicide carryover	8
Poor Root Growth	Compaction	6
Leaf Spot	Genetic	2
Leaf Mottle	Nutrient imbalance	1
Dead Plants	Lightning damage	1

TABLE 8.—Continued

Host Plant Diseases and/or Disorders	Causal Agent	Number of Samples
Glycine (SOYBEAN)		
Fusarium Root Rot	*Fusarium* sp.	1
Rhizoctonia Root Rot	*Rhizoctonia solani*	16
Phytophthora Root Rot	*Phytophthora megasperma* var. *sojae*	20
Pythium Seed Rot	*Pythium* sp.	1
Pod and Stem Blight	*Diaporthe phaseolorum* var. *sojae*	1
Stem Canker	*Diaporthe phaseolorum* var. *caulivora*	8
Brown Stem Rot	*Cephalosporim gregatum*	1
Charcoal Rot	*Macrophomina phaseolina*	8
Downy Mildew	*Peronospora manshurica*	2
Lesion Nematode	*Pratylenchus penetrans*	1
Lance Nematode	*Hoplolaimus galeatus*	1
Soybean Cyst Nematode	*Heterodera glycines*	5
Miscellaneous Disorders		
Stem Damage	Herbicide injury	3
Swollen Roots	Improper fertilizer application	1
Leaf Scorch	Herbicide splash	4
Leaf Curl	Herbicide drift	6
Leaf Chlorosis	Herbicide carryover	4
Leaf Spot	Manganese deficiency	3
Leaf Scorch	Environmental stress	3
Plants Dying	Lightning damage	1
Trifolium (CLOVER)		
Alfalfa Mosaic	Alfalfa Mosaic Virus	1
Medicago sativa (ALFALFA)		
Crown/Root Rot Complex	Various fungi and poor cultural conditions	1
Sclerotinia Crown & Stem Rot	*Sclerotinia trifoliorum*	2
Spring Blackstem	*Phoma medicaginis*	1
Root Rot	*Phytophthora megasperma*	5
Leaf Spot	*Leptosphaerulina briosiana*	4
Leaf Spot	*Pseudopeziza medicaginis*	5
Miscellaneous Disorder		
White Leaves	Herbicide carryover	1
Festuca (FESCUE)		
Barley Yellow Dwarf	Barley Yellow Dwarf Virus	1
Hedysarum (HAIRY VETCH)		
Miscellaneous Disorder		
Stunted Growth	Nutrient deficiency	1
Nicotiana (TOBACCO)		
Miscellaneous Disorder		
Leaf Scorch	Environmental stress	1

significant. Stem canker of soybeans was more prevalent than in previous years (1,2,3,4). The soybean cyst nematode was confirmed in five additional counties: Laporte, Starke, Jasper, Warren and Tippecanoe.

Diseases-Alfalfa: Common leaf spot, *Leptosphaerulina* leaf spot and spring blackstem were severe on alfalfa until the dry June weather occurred. *Phytophthora* root rot and crown rot complex of alfalfa were also observed early in the growing season.

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CELL BIOLOGY

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ABSTRACTS

Changes in Nucleic Acid and Protein Content in Nuclei of Human Cervical Cells. PRADEEP K. BHATTACHARYA, Department of Biology, Indiana University Northwest, Gary, Indiaa 46408 and Aristotel J. Pappelis, Department of Botany, Southern Illinois University, Carbondale, Illinois 62901.——Nuclei in five classes of cervical cells observed in Pap smears were studied using quantitative epifluorescence microscopy. The five classes of cells were: parabasal (Pb) cells; intermediate cells with round (I-R), oval (I-O), and rod-pyknotic (I-RP) nuclei; and pyknotic (P) cells. Six nuclear traits were measured: total nucleic acid, DNA, RNA, total protein, histone, and non-histone protein. The six nuclear indices increased as Pb cells became I-R cells (cell enlargement and maturation), and then decreased as I-R cells degenerated through the following senescense sequence: I-O, I-RP, and P. We infer that these changes continue and result in anucleate, superficial cells. Pb cells are probably in early stages of DNA synthesis (S-phase of the cell cycle) since the mean for DNA increased as they became I-R cells. The following types of cells comprised the Pap smears studies: Pb, 7.0%; I-R, 19.0%; I-O, 55.0%; I-RP, 8.0%; P, 9.0%; superficial cells with nuclei devoid of nucleic acids, 1.0% and anucleate cells, 1.0% We conclude that cervical exfoliative cytology provides a model system for the study of human cell development, maturation, senescence, and death in addition to its use in detecting early through late stages of cervical cancer. The high correlation between the nuclear indices studies suggests that several quantitative nuclear parameters other than DNA may be useful for cancer detection.

Genetic Differentiation among Populations of *Collinsia verna*. JUDITH K. GREENLEE, Department of Chemistry, University of Notre Dame, Notre Dame, Indiana 46556.——*Collinsia verna* (blue-eyed Mary) is an understory herb found on floodplains in the northern midwest, with populations sizes being very small and populations often separated by several miles. Since such isolation seemingly precludes gene flow among varius populations, the possibility of genetic differentiation leading to incipient speciation exists. Recently, *C. verna* populations were found to differ in several parameters including chiasmata frequencies, morphological characters and isozymic frequencies (Greenlee and Rai, 1983). The data from the above study showed considerable genetic divergence among populations. It was decided to extend these studies to include two additional parameters—the nuclear DNA amounts among various populations and other species, and the comparative karyotypes of *C. verna* and *C. heterophylla*.

The dogma in *Collinsia* cytology in the past has been that there are 7 pairs of metacentric chromosomes, which are approximately equal in size. The comparative karyotypes show that this is not the case for either species. Change in centromere position

indicative of pericentric inversions was seen in two pairs of chromosomes. Interspecific hybrids showed desynapsis and heteromorphic bivalents.

Populations of *C. verna* were examined by Feulgen cytophotometry to determine the extent of their variation and two other *Collinsia* species were measured for comparative purposes. Nearly a four fold difference in DNA amount was found among these populations, which were collected from a 300 mile area of the midwest.

While the pattern of determining factors is not entirely clear, the nearly four fold difference in DNA values combined with the karyotype evidence, and the parameteric differences previously found clearly show that genetic differentiation has occurred among these *Collinsia verna* populations.

Ontogenesis of a Calcium-binding Protein Specific to Brain. ZAFAR IQBAL, All-India Institute of Medical Sciences, New Delhi and Northwestern University Medical School, Chicago, Illinois 60611.——Calcium plays a significant role in the regulation of a number of key cellular processes. It is now recognized that most of the actions of calcium are mediated through calcium-binding protein(s). In developing chick embryo brain we have identified a calcium-binding protein which is organ specific and shows a developmental pattern identical to that observed for two key enzymes involved in nerve-conduction and transmission of impulses; viz., acetylcholinesterase and Na-K Atpase (Iqbal et al, J. Neurochem). 15:1217-1222; Iqbal & Talwar, J. Neurochem. 18:1261-1267). Employing acrylamide gel electrophoresis and immunochemical procedures, a detectable amount of protein was found on day 6 and the contents of the protein increased with age attaining a plateau on day 13, a period which coincides with the maturation of the electrical activity in brain. Whether this protein, through its calcium-binding property is involved directly in the manifestation of the functional activity of the brain is yet to be determined.

Real Time Visualization of Nerve Function Might Be Possible Using Magnetic Dyes. EDWARD A. KIMBLE/ITT Educational Services, Fort Wayne, Indiana 46825.——In most optical and ultrasound applications relating to nerve measurement, clear high speed measurements cannot be made due to high background and symmetry related noise problems. A method is suggested for using magnetic dyes to break the symmetry of the normally circular nerve fiber and to provide a mechanism for overcoming background signal effects. In this technique, a competition would be established between orientation of radio-opaque dye molecules by an external magnetic field and orientation by nerve related electric fields. Directional scattering would then be used to detect relaxation of electric fields. This technique could be applicable to x-ray, ultrasound, or Raman spectroscopic techniques. A prototype detector system for testing this concept and imaging x-ray scattering will be presented. Other approaches to the general problem will be discussed.

Effects of Selected Antifungal Agents on Hyphal Tip Growth in *Rhizoctonia solani*. GEORGE A. MECKLENBURG, KEVIN W. MILLER and STANLEY N. GROVE, Goshen College, Goshen, Indiana 46526.——In our continuing search for suitable probes to test the current model for hyphal tip growth we treated growing hyphal tips on slide cultures with growth media containing selected chemical agents. Within four minutes after application of 1.0 mM diamide tip growth slows to 40.0% of pretreatment growth rate and the phase contrast bright portion of the Spitzenkorper (apical body) retracts from its usual location adjacent to the apical wall. The usual organization of the cytoplasm becomes disrupted as evidenced by the abrupt loss of the typical orientation of mitochondria. Since diamide is reported to cause increased polymerization of actin our results may be explained as due to the limitations placed on the dynamic cytoskeleton. A pool of unpolymerized actin would seem necessary to allow the constant cytoskeletal

modification required to conform to the growing cytoplasm.

Eugenol (0.16 mM), an uncoupling agent in mitochondrial respiration, causes the Spitzenkorper to lose its phase dark component and leave the usual apical location with 25 sec. after treatment. This response is followed within 2 minutes by cessation of growth but some cytoplasmic motion persists for up to 15 minutes.

In tips treated with 5-cinnamic acid (0.16mM), which blocks Golgi mediated secretion, the growth rate drops to 25.0% within 2 minutes and then recovers slightly to about 30.0% after 5 minutes. The Spitzenkorper disappears at about 75 seconds and is not evident during the period of lowest growth rate but reappears just prior to the recovery at 5 minutes.

Naftifine (0.15 mM), which is thought to effect lipid metabolism, causes no measurable change in the growth rate for up to 12 minutes after treatment. These observations support the suggestion that the cytoskeleton and secretory phenomena are key elements in tip growing cells. It appears that eugenol and possibly other respiratory inhibitors will be useful in examining energy dependent elements while short effects on lipid metabolism may not be critical to tip growth.

Supported in part by Research Corporation and by the Goshen College Faculty Research Fund.

Micromanipulation of Exocytotic Aggregates from *Paramecium multimicronuleatum*. CHRISTOPHER C. SCHROEDER, THOMAS A COLE and WILLIS H. JOHNSON, Department of Biology, Wabash College, Crawfordsville, Indiana 47933.——Axenic, starved *Paramecium multimicronucleatum* cells rapidly take up fluorescent latex beads (1.5 micron diameter). After about one hour the beads begin to be eliminated as monodisperse units or as spherical aggregates of 30-40 beads. In order to determine whether the aggregates are bounded by a membrane, a micromanipulator for picking up these aggregates and transferring them one-by-one to fresh medium has been developed. When an isolated aggregate is damaged with a glass needle, the individual beads disperse rapidly. The stability of aggregates and synthetic lipid vesicles (liposomes) to the action of various agents has been compared. These results and an evaluation of the evidence concerning the question of whether the aggregates are membrane bound will be presented.

Mitochondrial Membrane Potential in Cytochalasin Treated Hyphal Tips of *Rhizoctonia solani*. MARVIN D. SLABAUGH and STANLEY N. GROVE, Goshen College, Goshen, Indiana 46526.——Within two minutes following application of cytochalasin A (CA) to growing hyphal tips the characteristic Spitzenkorper is disrupted, tip growth slows, and the tip becomes bulbous. To determine whether these responses to CA are due to inhibition of respiratory activity we used the cyanin dye 3,3′ diethyloxacarbocyanine [$DiOC_2(3)$] which is a membrane potential-dependent fluorescent probe for levels of mitochondrial activity. When growing hyphal tips on slide cultures are exposed to the dye dissolved in liquid growth medium and examined by epifluorescence microscopy at 450-490 nm excitation the mitochondria stain intensely while only two levels of stain are present in the cytoplasm. Upon the addition of CA in liquid growth medium to the stained hyphae the typical morphological changes occur and the stain remains in the mitochondria for up to 15 minutes. However, when the proton ionophore 2,4-dinitrophenol (DNP) which dissipates the mitochondrial trans-membrane potential is added in liquid growth medium the mitochondria lose their stain rapidly (by 30 sec) leaving a low level of cytoplasmic stain. These findings suggest that the actions of CA do not include inhibition in respiratory enzyme activities sufficient to alter the mitochondrial trans-membrane potential. Supported in part by a grant from Research Corporation.

Measurements of Cytosolic Calcium and Sodium During Acetyl-choline Stimulation of Parotid Salivary Glands. ROBERT J. STARK, Department of Zoology, DePauw University, Greencastle, Indiana 46135.——Conventional, calcium- and sodium-selective microelectrodes were used to examine the ionic mechanisms regulating salivary secretion in response to acetylcholine (ACh) stimulation. The concentration of free cytosolic calcium ([Ca]i) and sodium ([Na]i) in unstimulated cells was determined to be 0.44 ± 0.04 uM (n = 47) and 9.9 ± 1.2 mM (n = 29) respectively. By measuring the induced changes in intracellular electrode potentials (Em, E_{Ca}, & E_{Na}), ACh at 10^{-9}, 10^{-8}, 10^{-7}, 10^{-6}, & 10^{-5} M was observed to hyperpolarize Em by 0.0 ± 0.4, 1.4 ± 0.2, 4.9 ± 0.2, 8.4 ± 0.3, & 8.4 ± 0.5 mV; increase [Ca]i by 0.20 ± 0.02, 0.61 ± 0.04, 0.53 ± 0.02, 0.30 ± 0.05, & 0.14 ± 0.03; and increase [Na]i by 1.4 ± 0.1, 1.8 ± 0.1, 2.1 ± 0.3, 1.6 ± 0.3, & 1.7 ± 0.3 mM respectively. Even though ACh always induced an increase in [Ca]i, [Na]i and membrane hyperpolarization, the magnitude of the responses were dose-dependent with lower ACh concentrations (10^{-9} to 10^{-7}M) inducing dose-dependent increases in these parameters, while the cells appear to buffer the response to higher ACh concentrations by lmiting or reducing the magnitude of the increases in [Ca]i and [Na]i. The patterns of [Ca]i and [Na]i regulation during ACh stimulation appear to be similar indicating a possible linkage, while both are different from the induced membrane hyperpolarizations suggesting that stimulation of these exocrine glands with ACh may trigger at least two independent ionic events. (Supported by PHS Grant AM26246 and an Indiana Academy of Science Research Grant)

Silver Staining of Persistent Nucleoli in Mung Bean as a Valid Indicator of Synthetic Activity. MARTIN A. VAUGHAN, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809 and J. P. BRASELTON, Department of Botany, Ohio University, Athens, Ohio 45701.——In some animal and many plant cells the nucleolus remains more or less intact through metaphase of mitosis or later and are termed persistent nucleoli (PN). In several mammalian cell lines PN have been stained positively with silver nitrate. It has been proposed that the selectivity of this stain for the nucleolus and nucleolus organizing regions of chromosomes is due to interaction of the silver with certain proteins associated with the functionally active nucleous; such staining has therefore been used as an indicator of functionally active nucleoli.

The purpose of this study was: 1) to determine if and to what extent PN of a plant, the mung bean, stain with silver nitrate, 2) and to compare the ultrastructure of PN of mung bean to the ultrastructure of synthetically active interphase nucleoli.

Primary root tips of mung bean were prepared for light microscopy, then stained with silver nitrate or processed for transmission electron microscopy. Positively silver stained PN occurred in 76.0% of the metaphase figures scored in the mung bean, which others claim is suggestive that these PN are synthetically active. Ultrastructurally PN in mung bean at metaphase consist predominently of loose fibrils and a few scattered granules as opposed to the distinct fibrillar and granular regions typically of synthetically active interphase nucleoli.

Although silver staining has been used as an indicator of synthetically active nucleoli, ultrastructural evidence in the mung bean indicates that PN are structurally different than synthetically active interphase nucleoli. These data suggest that silver staining should not be used as an indicator of the synthetic activity of nucleoli until and unless definitive evidence for this correlation is developed.

Radiation Effects Studied with In Situ Fluorescence Spectroscopy Techniques

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Introduction

The importance of chromosomes and especially DNA as primary targets for the radiation induced inactivation of the function of cells is well recognized (1). However, it is also known that damage to irradiated cells may occur due to other processes, such as lipid peroxidation (2). This is a process to which membranes are especially susceptable resulting in the breakdown of existing structures due to reactions between unsaturated lipid, oxygen and free radicals; the latter component presumably formed by the impinging radiation. Since lipid peroxidation involves autocatalytic reactions, a minute radiation dose may have potentially drastic final effects. However, the degree to which the various radiation effects contribute to the disfunction or death of a particular cell category is in many cases not well established. This is especially true for cells of the nondividing type, such as neurons. DNA aberrations caused by irradiation may not be as critically damaging to these cells as to cells undergoing periodic mitosis. Lipid peroxidation reactions and other processes caused by irradiation may play an important role along with DNA aberrations, in determining the fate of the irradiated nondividing cells. Studies of irradiated, nondividing cells are therefore of special interest to establish the various factors responsible for cell disfunction.

Recent work by several authors has demonstrated the importance of lipid peroxidation processes for biological material exposed to radiation. Redpath and Patterson (3) have shown, for instance, that the radiosensitivity of E coli fatty acid auxotroph K - 1060 increases with the number of carbon-carbon double bonds in the fatty acid used in the growth medium. Since fatty acid double bonds are of key importance in lipid peroxidation reactions the result suggests a peroxidative process. In experiments by Konings and Drijver (4) mice which had received a diet deficient in vitamin E (a free radical scavenger) were more sensitive to X-irradiation than were normal mice. In particular the cellular membranes of the vitamin E deficient mice were more vulnerable to lipid peroxidation. It has been reported that X-rays and gamma rays as well as ultraviolet light produce hydroperoxide in lipid membranes (4).

In this paper we discuss an in situ fluorescence method designed to monitor processes related to lipid peroxidation reactions caused by irradiation of biological material. The fluorescence method does not directly register the primary steps in lipid peroxidation but detects effects due to certain compounds formed as byproducts, such as malonaldehyde. This molecule has the ability to crosslink other compounds such as available protein and form aminoiminopropane (AIP), which is a flurophore (see e.g. (5)). This compound becomes therefore an in situ crosslink. In model systems the AIP fluorophore has excitation and emission wavelengths of 400 nm and 465 nm respectively. Since the main damage to biomaterial in lipid peroxidation reactions is caused by products like malonaldehyde the fluorescence method can be regarded as a good indicator of the process (5). It is of importance in measurements of this type to note that the discussed reaction is progressing at a very slow rate. The increase in the AIP fluorophore concentration in model systems (6) has a half-time of the order of 24-48 hours. Fluorescence from AIP formed in irradiated tissue should therefore increase slowly to saturation over a period of several days.

Materials and Methods

A schematic block diagram of the in situ fluorometer used in the experiments described in this paper is shown in Figure 1. Excitation light from a conventional incandescent filament light source is selected in a Schoeffel miniature monochromator and enters a Y-shaped light guide (a Schott ultraviolet transmission guide). The diameter of the shaft of this guide is 0.3 cm. The end part of the shaft is positioned in a cannula attached to the sample to be investigated (as described below and Figure 2) which is thereby exposed to the appropriate excitation light. Fluorescence light returns through the same guide and part of this light is led through the second arm of the Y-guide to a second monochromator (a Schoeffel double monochromator, G 200) tuned to the fluorescence wavelength. The transmitted light is finally registered in a single photon counting detector (a RCA photomultiplier).

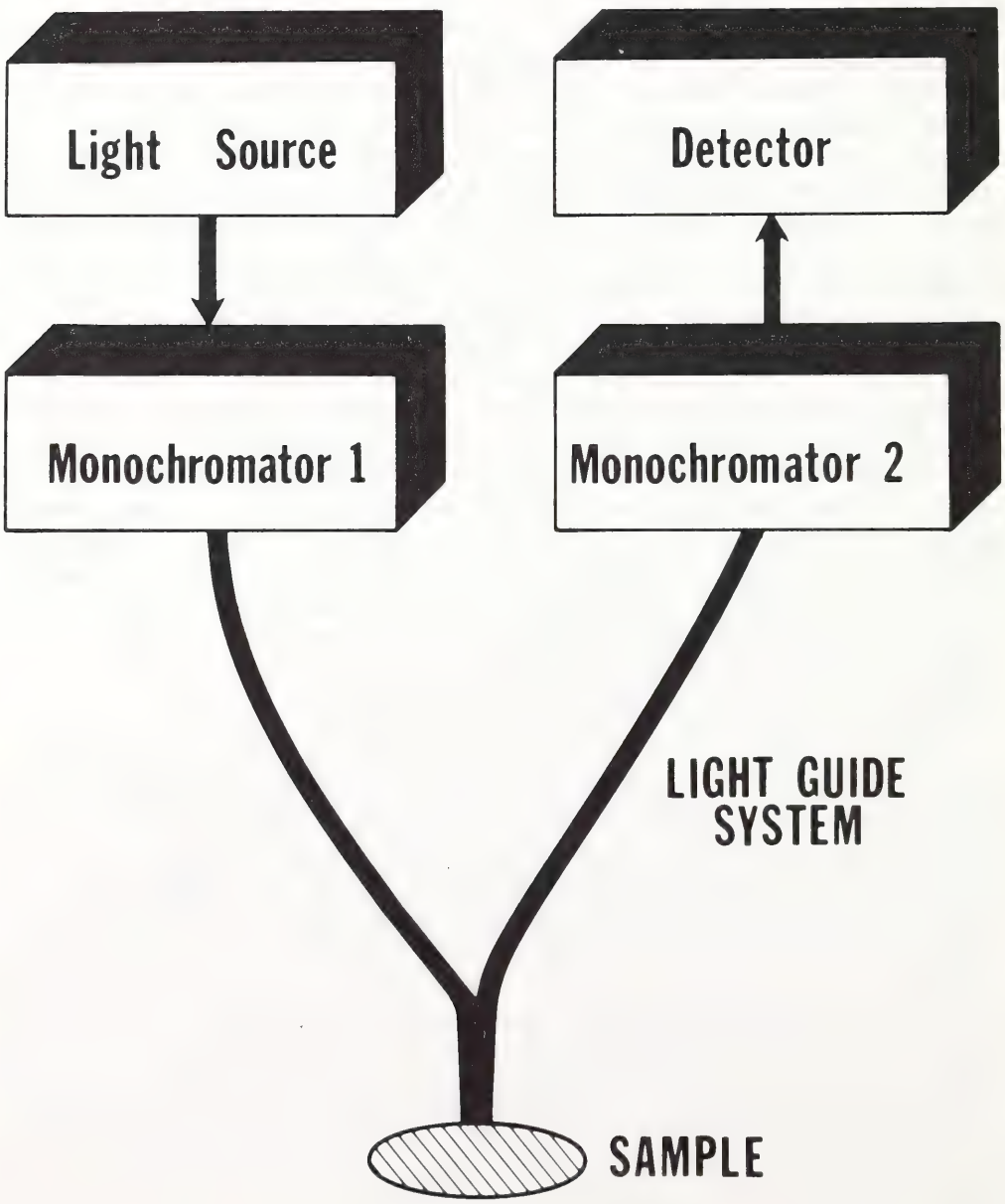

FIGURE 1 *Block diagram of in situ fluorometer.*

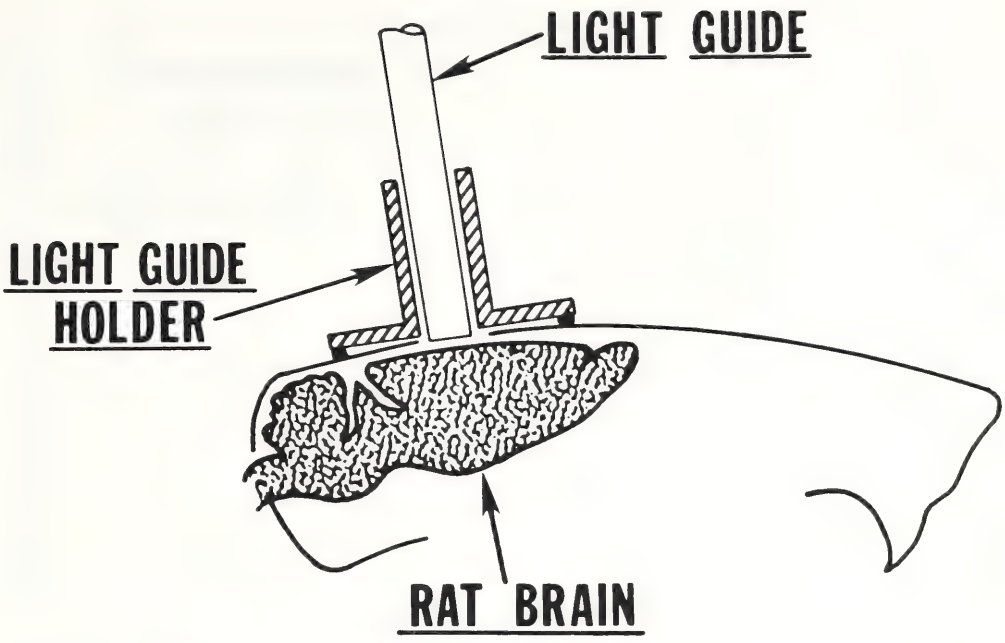

FIGURE 2 *Cross section diagram of a rat skull showing approximate positioning of the light guide.*

To observe fluorescence from the surface of a rat brain over an extended period of time, which was necessary in the present investigation, a chronically implanted cannula was introduced to hold the light guide in position (see Figure 2). A hole, approximately 0.5 cm in diameter was drilled in the parietal bone over the brain area of interest. The cannula was then fixed in place over the hole by acrylic dental cement. This arrangement has been tested in this laboratory and shown to be operative for several days.

Male Wistar rats in the age range 3-6 months were exposed to 1000 rad of gamma rays without anesthesia in wholebrain irradiations from a ^{60} Co source. The source-to-skin distance was 1 m. All parts except the head of the rats were shielded by 4 inches of lead. Prior to irradiation the light guide cannula was implanted surgically in all rats using ether as the anesthetic. A fluorometric measurement at excitation and emission wavelengths 400 nm and 465 nm were performed. After irradiation periodic scans at this fluorometric setting were done for five to seven days. After this time period the cannula arrangement started to deteriorate and was not reliable for accurate measurements. The animals were kept on regular diets during the entire experiment. The instrument was periodically calibrated with a standard quinine sulfate sample.

Results and Discussion

Figure 3 shows a representative fluorescence spectrum of rat brain tissue recorded at excitation wavelength 400 nm and prior to irradiation (time 0) and four days after irradiation (time 96 h) using the procedure discussed in the previous section. A more detailed graph of the time course of the change in the fluorescence peak at wavelength 465 nm is given in Figure 4. Data points in this figure represent the integrated area under the fluorescence emission peak corrected for light scattering effects. The slight decrease of the fluorescence intensity at time approximately seven days is probably due to repair processes in the tissue. Control experiments with non irradiated animals

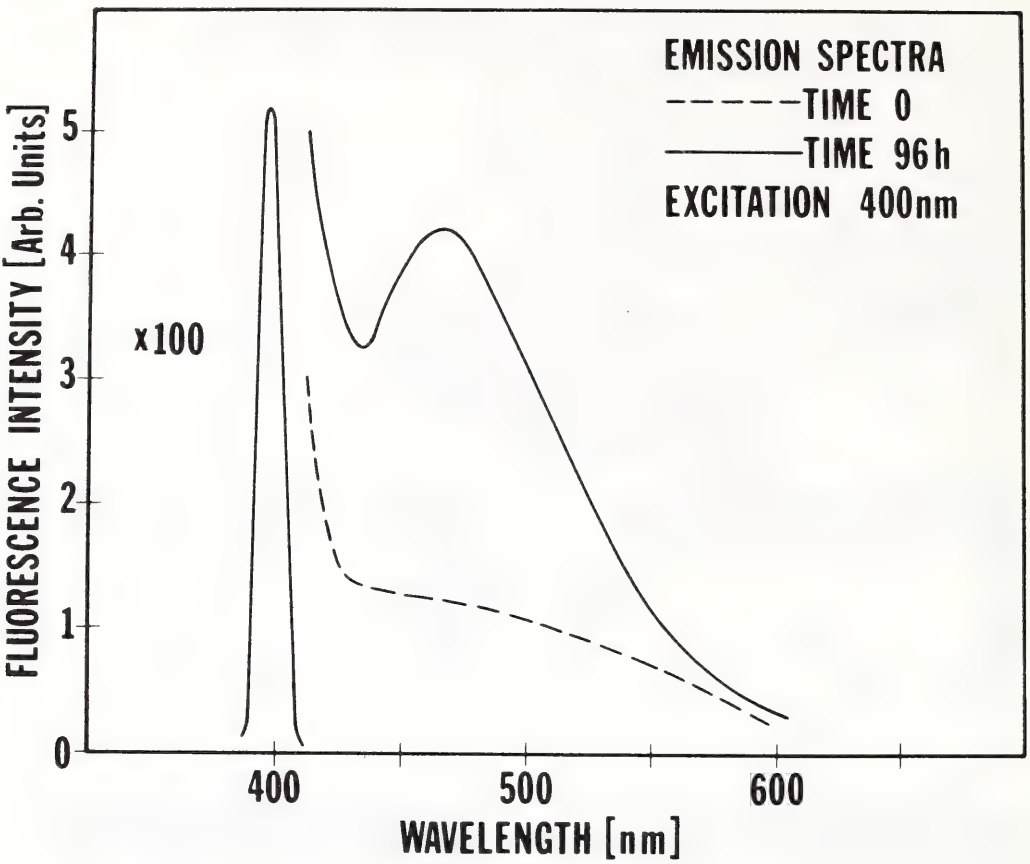

FIGURE 3 *Representative fluorescence emission spectra of irradiated tissue as measured by the in situ light guide probe shown in Figure 1 and Figure 2.*

did not show any significant change in fluorescence at the appropriate wavelengths during the time interval of interest.

The interpretation of the fluorescence peak as being due to AIP formed in lipid peroxidation processes is based partly on previous results showing that such reactions do occur in the irradiated tissue (7,8) and partly on experiments with model systems in which proteins and other cell components have been incubated with the compound malonaldehyde, a known product in lipid peroxidation reactions (6). In the model system a series of experiments with rat liver mitochondrial ghosts as well as bovine serum albumin were reacted with malonaldehyde. In both cases two main fluorescence changes were detected. Protein fluorescence as observed at excitation and emission wavelengths of 295 nm and 340 nm respectively decreased with half-time of approximately two hours and was completely quenched after a period of ten hours. A newly formed fluorophore interpreted to be AIP, observed at excitation and emission wavelengths of 400 nm and 465 nm respectively reached a maximum with a much slower rate; the half-time was approximately 24 hours for pure protein and 48 hours for mitochondrial ghosts. These experiments support the hypothesis that a two step reaction takes place. First malonaldehyde reacts with protein quenching its flurorescence and then fluorescent interprotein AIP crosslinks are formed.

If the model system experiments were directly applicable to the in vivo situation studied here a change in the protein fluorescence would also be expected. Measurements of the protein fluorescence in the present system indicated a slight decrease in intensity,

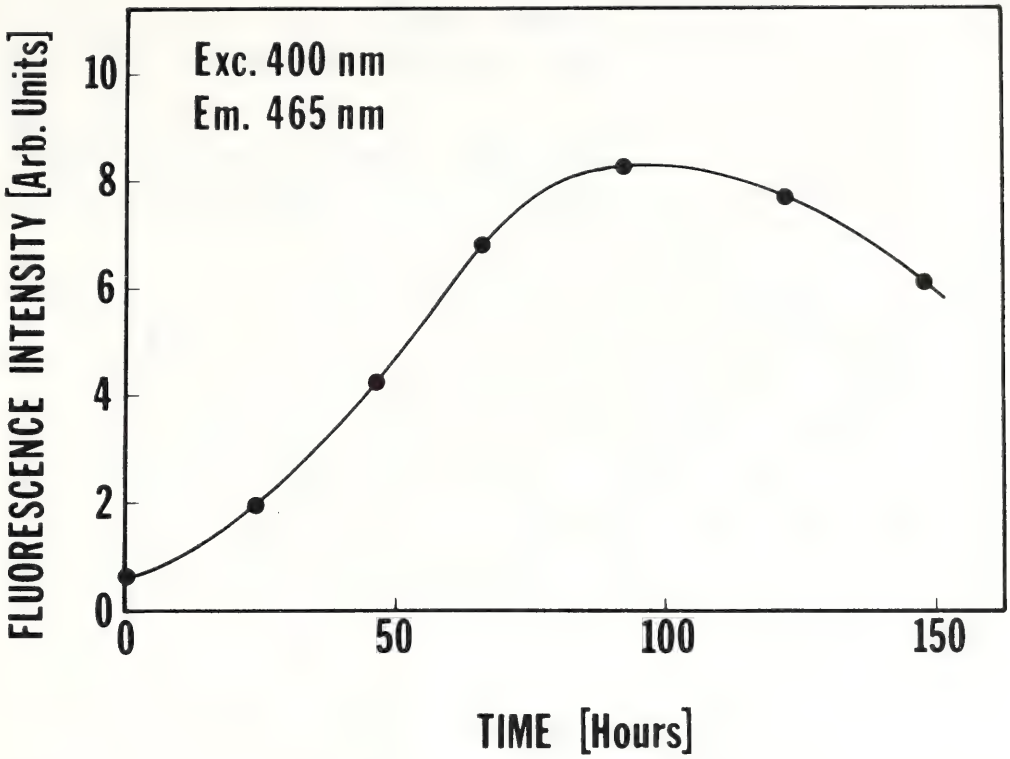

FIGURE 4 *Time course of the fluorescence light at emission wavelength 465 nm of irradiated tissue. Data points represent the integrated area under the fluorescence emission peak shown in Figure 3.*

but no complete quenching took place as in the model system. This is not surprising since it is reasonable to assume that only a fraction of the brain tissue is affected by the irradiation and a total disappearing of protein fluorescence is therefore not likely. An accurate masurement of this change could therefore be used to estimate the amount of affected irradiated tissue. Such a measurement may be developed into an assay method of lipid peroxidation destruction processes if indeed it is shown that it is an importnat contributing factor in injury of irradiated tissue.

As demonstrtaed in this work the in situ technique allows the registration of the time course of radiation effects in single animals. This offers some advantages over conventional methods. An example is repair of irradiated tissue. The data in Figure 4 seem to indicate that the intensity of fluorescence of AIP decrease after a certain time period. This probably means that affected tissue is being repaired with subsequent removal of AIP compounds. A detailed in situ study with somewhat improved technique may allow observation of the time course of this effect over an extended period of time with repeated exposure of radiation and subsequent repair in individual animals. The in situ method also makes it possible to avoid certain artifacts that may be introduced by preparation of samples from sacrificed animals. This is often of importance in lipid peroxidation investigations since tissue removed from its natural environment with its defense systems often show an enhanced lipid peroxidation effect.

Acknowledgment

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Long-term Culture of Epithelial Cells Derived from Axolotl (*Ambystoma mexicanum*) Embryos

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Introduction

The Mexican axolotl (*Ambystoma mexicanum*) has considerable research potential in developmental biology, cell physiology, and cell differentiation because of its known mutants (5). A first step into the investigation of the cellular and molecular basis of cell lethality in autonomous cell-lethal mutant axolotl embryos (5) requires the long-term cultivation of axolotl embryo cells past the essential metabolite stores of embryonic cells.

The long-term cultivation of amphibian cells has been worked out for many anurans (3, 7). Except for one urodele cell line (TVI) (7) the number of reports on the long term cultivation of urodele cells is sparse and there is no report on the long term cultivation of axolotl cells in the literature. The culture requirements and methodologies for the long-term culture of urodeles in general and axolotls specifically still need to be established.

This report describes the first long-term cultivation of epithelial cells derived from normal axolotl prehatching embryos. The procedure depends on the establishment of primary explant embryo cultures that select for vigorous epithelial cell growth and the subsequent subcultivation of epithelial cultures not as dissociated single cells but as pieces of epithelial sheets (50 to 200 cells/piece).

Methods and Materials

Primary Explant Culture: Nine individual stage 36-38 (1) normal axolotl prehatching embryos from the Indiana University Axolotl Colony (Bloomington, Indiana) were explant cultured in individual culture dishes. Individual embryos preincubated in 20% Steinberg's solution (S) with antibiotics (Penicilln-Streptomycin 5 mcg/ml each and Fungizone 2.5 mcg/ml at pH 7.4) from 2 to 24 hours in their jelly coats were sequentially immersed (20 seconds) in 1% hypochlorite (Chlorox) in 20% S; 20% S with antibiotics; 70% Ethanol in 20% S and then washed 3 times in 20% S with antibiotics. Mechanically dejellied embryos were anesthetized in 1/50000 MS-222 (ethyl-m-aminobenzoate, methane sulfonic acid; Aldrich Chemical Co., Milwaukee, WI in 100% S with antibiotics (Gentamicin 50 mcg/ml), skinned (tail, torso, and head), and the yolky abdomen removed. The dissected embryos were transferred to complete culture medium: 55 parts Leibovitz's L-15, 25 parts doubly distilled H_2), 20 parts Fetal Bovine Serum (Flow Laboratories, Lot -29101338, McLean, Virginia), 0.02 U/ml insulin (Sigma), 1 ug/ml thyroxin (Sigma), 50 mcg/ml Kanamycin, 2.5 mcg/ml Fungizone at pH 7.8 $\pm$ 1. The embryos were minced into 0.5 to 1 mm diameter pieces and the pieces transferred to wet 35 mm tissue culture dishes (Corning) or glass petri dishes, prewashed with complete medium, with a minimal amount of culture medium. After a 2 hour incubation in a humid atmosphere at 25 °C, 0.5 ml of culture medium was added without disturbing the attached explants. At 24 hours the culture medium volume was increased to 1.5 ml. Every third day the cultures were fed with 1.5 culture medium.

Subculturing: The primary or subsequent subcultures were washed with 2 ml 75% L-15, washed again with 2 ml Ca^{+} and Mg^{2+} free PBS and then incubated from 30 to 60 minutes with 1 ml dissociation medium containing 1.8 U/ml Protease type IX

from *Bacillus polymyxa* (Sigma) in Ca^{2+} and Mg^{2+} free PBS, at 25 °C in a rotatory shaker (60 rev/min). The dissociation medium was collected, its volume doubled with complete medium and centrifuged (setting 3) on a desk-top centrifuge (IEC) for 2 minutes. An equal volume of complete medium was added, and the pellet was disrupted into small pieces (approximately 50 to 200 cells per piece) with repeated pipeting with a small bore pipette. The pieces were centrifuged as described above and the pellet resuspended in (1.5, 3, or 6 ml) complete medium. The pieces were plated in 35 mm tissue culture dishes (Corning) or 35 mm glass petri dishes at 1.5 ml per dish. The cultures were incubated in a humid atmosphere at 25 °C and fed 1.5 ml complete medium every three days.

Morphology and Cell Packing Density: Cell cultures were observed directly (phase), indirectly (video recordings, Panasonic) or by standard histological techniques. The mean cell packing density was determined by enumerating the number of cells occupying 0.1 mm^2, on photographs of at least 4 separate areas.

Proliferation: The large cell size and monolayer growth of these cells made it possible to determine the mitotic index (MI) and duration of mitosis (T_M) quite accurately. The MI was calculated as the ratio of mitotic cells (M) to total cells (Interphase (I) and mitotic cells) expressed a % ($M/I+M$) x 100). Cell cycle time (T) was estimated from MI and T_M according to the relationship $T = \log_e 2\ T_m/MI$ (8).

Results and Discussion

Primary Explant Culture: Eighty five percent to 95 percent of the embryo explants showed cell outgrowths by 24 hours in culture. Proliferation began by day 5, and beating heart cells and cilia cells, extensive nerve fiber outgrowths, and muscle cell differentiation were observed during the 56 to 78 days the primary cultures were maintained. Although there was a gradual decrease in the number of explants with cell outgrowths (day 36, 55%; day 50, 27%) by day 25 each culture had at least one proliferating monolayer epithelial outgrowth demonstrating homogenous cell morphology and an increase in cell packing density and epithelial sheet area. The origin of the epithelial cells is unknown. Cell morphology, culture behavior, and the fact that the embryos were skinned indicates that the epithelial cells are not epidermal cells.

Subculturing: Preliminary attempts to subculture primary cultures having epithelial sheets with the following dissociation media were unsuccessful: 0.25% trypsin (GIBCO); 1.8 units/ml protease (Type IX, Sigma); 0.125 trypsin and 0.9% protease (all in phosphate buffered saline diluted to 200 m Osm (PBS) without Ca^{2+} and Mg^{2+}, pH 7.2 at 25 °C. Typically, in 1:1 and 1:2 split ratios, from 1 to 9% of the cells attached. Similar dissociation conditions on 18 day primary cultures resulted in 20 to 50% cell attachment. There was a gradual degeneration of cells and by 18 days in culture few cells remained attached to the substrate. Mitosis was only observed in patches of confluent cells that platted as aggregates. These observations were used to successfully subculture epithelial sheet cultures by dissociating the epithelial sheets into pieces of approximately 50-200 cells each by the procedure outlined in the materials and methods.

Subcultured individual cells and epithelial sheet pieces attached with 24 hours. All the single cells eventualy degenerated and most epithelial sheet explants lost their confluency and eventually degenerated. About 10% of the epithelial sheet explants retained confluency and showed vigorous growth. These epithelial sheets increased both in cell packing density and area (Table 1) and were morphologically indistinguishable from the primary epithelial sheets. Cultures were subcultured when the majority of epithelial sheets achieved 30-50 $x10^4$ cells/cm^2. These epithelial sheets were cultured for 305 days and subcultured 4 times (78, 173, 230, and 290 days after culture initia-

TABLE 1
Cell Packing Density and Areas of Epithelial Sheets

Days in culture	Days after subculturing	Low packing density	High packing density	Mean packing density	Area of sheet
60	primary culture	15.5 ±2.5 a)	30.3 ±4.3	22.9 ±8.5	29 mm^2
173	95	—	—	55.7 [±12.0]	39 mm^2
186	13 b)	—	—	6.4 [±1.3]	.9 mm^2
203	30 c)	8.8 ±1.0	19.2 ±4.8	15.0 ±6.5	11 mm^2

The data is the mean ± SD a) of at least 4 separate counts of the number of cells occupying 0.1 mm^2. The packing density is expressed as 10^4 cells/cm^2. b) and c) represent data on the same epithelial sheet.

tion), before they were lost due to an inadvertant switch to a different lot of fetal bovine serum. Cultures were negative for both mycoplasmal contamination (direct agar technique) (4), and bacterial contamination (microscopy) (2). This same lot of fetal bovine serum did not support the initiation of new epithelial sheets from primary cultures.

Morphology and Cell Packing Density: During the long term cultivation of these epithelial cells there was no change in cell morphology or any obvious change in chromosome number (Figure 1). The highest cell packing density observed was 55.7 x 10^4 cells/cm^2. This was probably their saturation density because proliferation was occurring simultaneously with cell detachment with no net change in cell packing density.

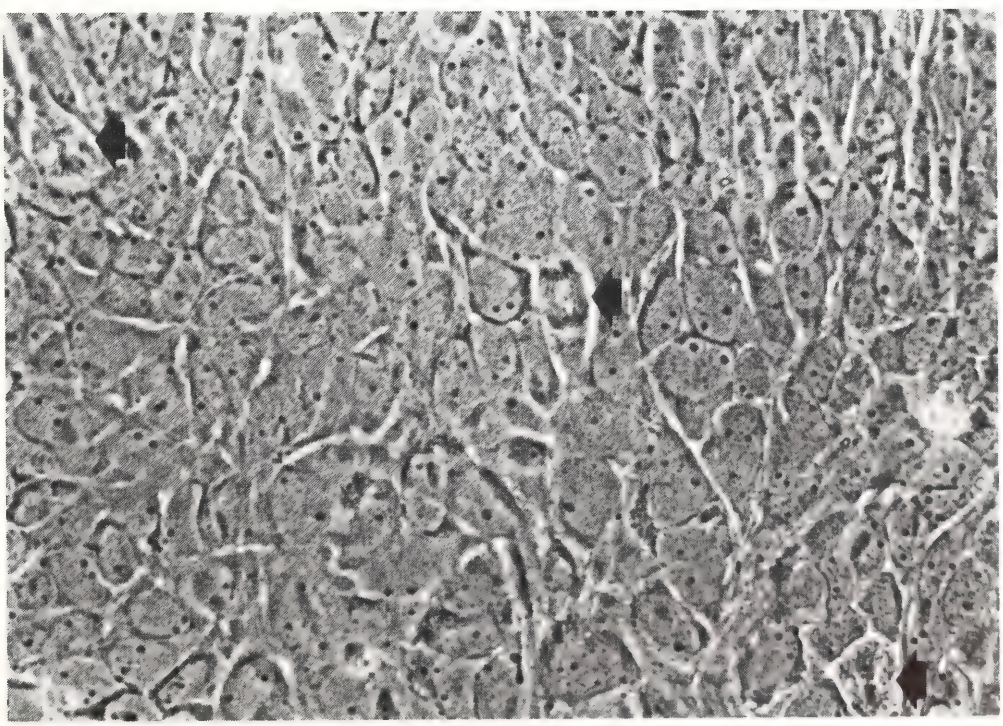

FIGURE 1 *Phase micrograph of an epithelial sheet 211 days in culture showing typical cell morphology, low and high cell packing densities and several mitotic cells (arrows). (193 x magnification)*

Proliferation: Proliferation was evident at 5 days in primary cultures and 2 to 5 days after subcultivation. Proliferation was evident at all cell packing densities throughout the epithelial sheets. Mitosis was only observed among confluent cells. The MI, T_M and T for epithelial cells during the first and second subculture (Table 2) remained

TABLE 2
Mitotic Index, Duration of Mitosis and Estimated Cell Cycle Time in Epithelial Cell Cultures

Days in culture	Mitotic Index (MI)	Duration of Mitosis (T_M) (minutes)	Estimated Cell cycle time (T) (hours)
80-109 (first subculture)	1.2 ±.8	80 ±25	46
179-215 (second subculture)	1.1 ±.3	80 ±18	50

The cell cycle time was estimated using the relationship $T = \log_e 2\ T_M/MI$ (8). Data represents the mean ± SD of at least 9 measurements during the culture periods indicated.

constant. Spot checks of the MI and T_M during the fourth subculture (data not shown) gave similar values. These values lie within the range usually reported for amphibians (7). The observation that during the long-term cultivation of these epithelial sheets the morphology of epithelial cells and sheets remained constant, that the culture behavior of the epithelial cells and sheets remained constant, and that there was no dramatic change in chromosome numbers indicates the possibility that these cells probably did not transform. These observations are consistent with the observation that chromosome number of amphibian cell lines tend to be stable and amphibian cell lines are frequently epitheliod and have no intrinsic senescenee phase (6, 7). The axolotl epithelial cell sensitivity to fetal bovine serum and requirement for cell-cell contact for active proliferation may explain why the establishment of long-term cultures of axolotl cells has been difficult. In this light the first long-term cultiviation of epithelial cells from prehatching axolotl embryos, described in this study, is important for the eventual establishment of cell lines from normal and mutant axolotls.

Acknowledgments

The author thanks Dr. George M. Malacinski and Dr. Anthony L. Mescher for helpful discussions and advice and Debbie Brinegar for skillful secretarial assistance. This project was supported in whole or in par by funds provided by the Herbert L. Ihrig Bequest through the Biomedical Research Support Program (Indiana University; Indiana School of Medicine).

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CHEMISTRY

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ABSTRACTS

Modification of the Classical Preparative Method of Carbonyl 2,4-Dinitrophenylhydrazones. JOSEPH L. BOLAN, MICHAEL FLYNT and MOHAMMAD BEHFOROUZ, Department of Chemistry and Burris Laboratory School, Ball State University, Muncie, Indiana 47306.——Frequently, the existing classical method for the preparation of 2,4-dinitrophenylhydrazones of Carbonyl compounds gives lower melting derivatives, even after recrystallization of the products. We found that by a slight modification of the general procedure this problem can be solved, and the results can be reproducible and improved appreciably. The modification simply involves a wash of the 2,4-DNP crystals with a 5.0% sodium bicarbonate solution. A series of aldehydes and ketones were selected and their 2,4-DNP derivatives were prepared by both methods and their melting points were compared. It was found that: a) in nearly all cases the melting points of the derivatives obtained by the modified method were higher than those obtained by the old method and b) the modified method gave more reproducible results.

Regiospecific Addition of Organocuprate Reagents to α, β **-unsaturated Esters.** JOSEPH L. BOLAN and MOHAMMAD BEHFOROUZ, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——A series of organocuprate complexes were made *in situ* by the reactions of the corresponding Grignard reagents with cuprous thiophenoxide (PhSCu) and the reactions of these complexes with, α, β-unsaturated esters were studied:

$$RMgX + PhScu \rightarrow RCuSPhMgX$$

$$R'-\underset{|}{C}=\underset{|}{C}-CO_2Me + \underset{Mg\ X}{RCuSPh} \rightarrow R'-\underset{R}{\overset{|}{\underset{|}{C}}}-\underset{H}{\overset{|}{\underset{|}{C}}}-CO_2Me$$

R = Alkyl R′ = Aryl and alkyl

High yields of saturated esters when obtained when R′ is aryl. No detectable amounts of 1,2-addition products even with a hindered alkyl group such as *t*-butyl were obtained. This indicates the regiospecificity of this reaction and its potential application in organic synthesis. The result of the studies on the addition of cuprate complexes to aliphatic esters (R = alkyl) also will be reported.

On-line Data Acquisition and Reduction System for Lineweaver-Burk Enzyme Kinetics Studies Using a U.V.-Visible Spectrophotometer and an Apple II Plus Microcomputer. STANLEY L. BURDEN, Department of Chemistry, Taylor University, Upland, Indiana 46989, and STEVEN E. NYGREN, NALCO Chemical Company, Chicago, Illinois 60638.——Software has been written and hardware configured to interface an Apple II Plus microcomputer to a Coleman 124 u.v.-visible spectrophotometer and log absorbance vs. time data for enzyme kinetics experiments as well as do a Lineweaver-Burk analysis. The software was written to utilize the commercially "ADALAB" and

"ADA AMP" but all software was written to optimize the enzyme kinetics studies. No commercial software was used. The system is menu driven and provides options to plot A vs. t data in real time and store this data as a binary file on a floppy disk. The data can then be rescaled, labeled and replotted on the monitor and/or printer. The user can then request a least squares fit to be made of any desired segment of the data to determine the best approximation of the initial slope. Initial slope and substrate concentration data is then entered and a Lineweaver-Burk analysis is performed. The constants of interest are determined from a least squares fit to this data and a plot is made using high resolution color graphics. The system was tested using the ADH - methanol system and the results were superior to those from hand computations.

Concentration and pH Dependent Stability of Sodium Thiosulfate Solutions. SHRIKRISHNA W. DHAWALE and BRIAN SHORT, Department of Chemistry, Indiana University East, Richmond, Indiana 47374.——In the present investigation, the effect of various factors such as concentration, pH, and presence of some metal on the stability of $S_2O_3^{--}$ ion in aqueous solutions has been studied.

Sodium thiosulfate slowly changes in titer with lapse of time. Thiosulfate solutions at various concentrations and pH values were titrated at time intervals. Some short term pH dependent stability experiments were performed. Effect of the presence of metal was examined in a similar way.

Some of the general conclusions of the present work are:
(1) At lower concentrations, $S_2O_3^{--}$ ions are destabilized to greater extent.
(2) At about the same pH range, less concentrated solutions are more unstable.
(3) Amongst metals or 304 stainless steel, copper has more destabilizing effect on $S_2O_3^{--}$.
(4) The lower the concentration of solution, the greater is the effect of copper.
(5) pH titration of $S_2O_3^{--}$ against HCl or H_2SO_4 show buffering action. The pH range of strong buffering action depends on $S_2O_3^{--}$ concentration.
(6) Metals like Ni and Zinc dissolve, forming their ions. Some crevice corrosion in 304 stainless steel was detected.

Further studies are in progress.

The Reaction of Aroyl Chlorides with 1,1-Dichloroethene: The First Reported Synthesis of β,β,β-Trichloropropiophenones. H. E. DUNN, B. G. ADDISON, P. A. PETERS, and M. J. PHILLIPS, Department of Chemistry, Indiana State University Evansville, Evansville, Indiana 47712, and C. Y. Meyers and T. N. Schmitz, Department of Chemistry and Biochemistry, Southern Illinois University, Carbondale, Illinois 62901.——It has been reported in the literature that β,β- dichloroacrylophenones can be prepared by the reaction of the appropriate aroyl chloride with 1,1-dichloroethene in the presence of aluminum chloride. By a slight modification of this procedure we were able to prepare a variety of ring substituted β,β,β-trichloropropiophenones, a previously unreported class of compounds. The β,β,β-trichloropropiophenones can be converted into the corresponding β,β-dichloroacrylophenones by heating, or by treatment with triethylamine. When stored in a glass container at room temperature in the laboratory, β,β,β-trichloropropiophenone, an oil, was found to slowly emit hydrogen chloride and convert to β,β-dichloroacrylophenone. On the other hand, p-$\beta,\beta,\beta,$-tetrachloropropiophenone, a white crystalline solid, appears to be quite stable under the same storage conditions. The synthesis, spectra, and reactions of this new class of compounds will be discussed.

The Design of a High Pressure Liquid Chromatography-based System for the Quantitative Determination of Denaturant-stable Protease Cleavage Specificities. JEFFREY

A. GORDON and ERIC R. JOHNSON, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——High Pressure Liquid Chromatography was utilized in a system designed to obtain quantitative data for the hydrolytic cleavage of small peptides catalyzed by guanidine-stable chymoelastase. This system is based on the fact that, each time a peptide of known amino acid sequence is cleaved, a free alpha-amino group is produced. This N-terminal amino acid can be identified and directly related to the site of cleavage within the peptide. Upon cleavage of the peptide by guanidine-stable chymoelastase, the newly produced N-terminal groups were then labelled with dansyl chloride and the remaining peptide bonds were hydrolyzed with 6.0 *M* hydrochloric acid. The dansylated amino acids were then separated by reverse-phase isocratic high pressure liquid chromatography and detected with a fluorescent spectrophotometer. By comparison of the separated dansylated amino acids with standards, it was possible to identify where the peptide cleavage had occurred. Furthermore, the chromatographed peaks for the dansylated amino acids were integrated in order to quantitate the extent of cleavage occurring at the hydrolysis sites. It was also found that, without any adverse effects to the dansylation process or to the HPLC separation of the dansylated amino acids, this system can operate efficiently with the presence of 6.0 *M* guanidinium chloride in the peptide hydrolysate. These observations show that the system can be used for the identification of peptide cleavage sites for denaturant-stable proteolytic enzymes functioning in the presence of denaturant.

A Comprehensive One-year Chemical Study of Acid Precipitation across Central Indiana. WILLIAM GROSS and JAMES P. RYBARCZYK, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Rain events from October 1982 to October 1983 were collected throughout central Indiana by volunteer members of Rotary International District 656. The area of interest encompassed 25 separate sampling sites and extended from West Lebanon and Rockville in the west to Union City and Richmond in the east. Over 1100 samples were collected and analyzed from 115 individual rain events. The rain water was analyzed for pH, ion conductivity, Ca ion, Mg ion, Na ion, K ion, sulfate ion, and nitrate ion. Each sample was also categorized by such meteorological conditions as wind direction, pressure movements, temperature, and time. The "average" pH across this region was found to be in the 4.0 - 4.3 range, with a seasonal change to a 3.2 - 3.5 average in hot summer thunderstorms. Little pH or ion concentration variations were noted across the state, suggesting that Indiana neither enhances nor decreases the acid content of already acidic rain that enters its borders.

Exploratory Experiments in Thermometric Titrimetry Using Hypohalites as Oxidimetric Reagents. DEBORAH L. GUTTMAN, Eli Lilly Company, Indianapolis, Indiana 46296 and A. J. C. L. Hogarth, Department of Chemistry, DePauw University, Greencastle, Indiana 46135.——Since the early fifties thermometric titrimetry has been shown to be a useful method for quantitative analysis, and many chemical systems have been investigated. One type of chemical reaction that has been neglected until recently is the REDOX system, and only a few workers have reported results. This is a peculiar oversight since it is known that considerable heats of reaction may be involved, in some cases as many as 20 Kcal/electron.

This paper deals with results obtained in a preliminary investigation of the reaction between selected ammonium salts and urea, and alkaline solutions of hypohalites. It is shown that the method, even with the use of classical apparatus, may be used to determine the percentage of nitrogen in certain fertilizers. It is clear that the method is limited by the sensitivity of the thermometer and that it is not selective, *ie*: if a mixed fertilizer were to be analyzed, the two or more components could not be determined individually. Precision for the method was found to be better than 3.0% (rsd)

for single compounds, and a single analysis was found to take no more than about one minute.

Permanganate Oxidations of Aldehydes in Non-aqueous Media. F. J. HADLEY, J. BONDI and I. SCHWARTZMAN, Department of Chemistry, Wabash College, Crawfordsville, Indiana 47933.——Permanganate oxidations have seen infrequent use as a synthetic tool because of solubility problems necessitating two phases. The recent use of crown ethers as phase transfer catalysts for solubilizing potassium permanganate in benzene and other non-polar solvents allows oxidation reactions to proceed in a single organic phase. We have investigated the kinetics of aldehyde oxidations in chlorobenzene. In particular, rate laws and thermodynamic parameters were determined for a series of aliphatic aldehydes. Also, Taft plots were constructed, and ESR spin-trapping studies were undertaken in order to identify the nature of the transition stage. Finally, a kinetic isotope study showed that C-H bond fragmentation was involved in the rate step. Comparisons were made with the accepted mechanism in aqueous acidic solution.

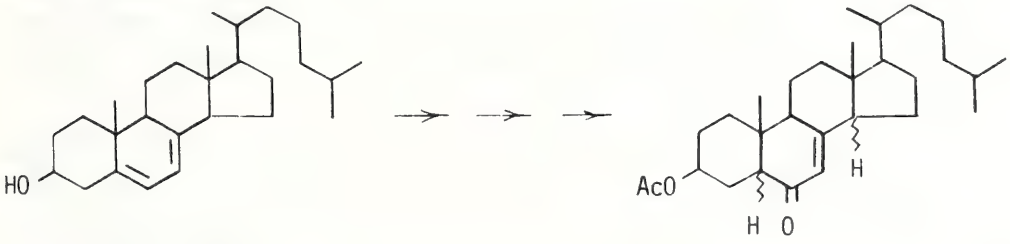
A Kinetic Study of the Reaction of $W(CO)_4$(phosphine)(pyridine) Complexes with Phosphines. CHERYL K. HOSTETLER and JOHN A. MOSBO, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——The reactions of $W(CO)_4(L)$(pyridine) complexes with L′ (L and L′ are phosphines) produce *cis* and *trans* $W(CO)_4(L)(L')$ products plus pyridine. Two kinetic studies of this reaction have been performed with L = PPh_2Et. In the first, the rates of reaction were determined as a function of ligand concentrations. Complex to reactant ligand (L′ = PPh_2Et) ratios of 1:2, 1:4, 1:8 and 1:16 were utilized. In the second study, three different reactant ligands (L′ = $P(n\text{-}Bu)_3$, $PPhMe_2$, or PPh_2Et) were employed using identical complex to ligand ratios of 1:4. Concentrations of the tungsten starting materials and products as a function of time were determined by periodic integration of ^{31}p nmr spectra. The rate data obtained from both studies were consistent with a first order reaction. The results were discussed in terms of a proposed mechanism.

Quantitative Assessment of the Cleavage Preference of Guanidine-stable Chymoelastase in the Presence of Denaturant. REBECCA M. LAMKIN and ERIC R. JOHNSON, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Guanidine-stable chymoelastase, a bacterial protease known to be stable and active in denaturant, was studied with respect to its cleavage preference in 6.0 *M* guanidinium chloride. Peptides of known amino acid sequence were incubated with the stable protease in the presence and absence of 6.0 *M* guanidinium chloride. The new N-terminal peptide groups produced by the protease action were then labelled with dansyl chloride. Following hydrolysis, the dansylated amino acids were identified and quantitated by reverse phase high pressure liquid chromatography. In the absence of the denaturant, specific cleavage occurred on the C-terminal side of phenylalanyl, tyrosyl, and leucyl peptide bonds, which is in agreement with previous studies. In the presence of denaturant, the rate of peptide bond cleavage was found to be substantially lower. However, the peptide substrates were hydrolyzed at the same positions, which indicates that this stable enzyme retains its cleavage preference for phenylalanyl, tyrosyl, and leucyl peptide bonds in the presence of denaturant.

Rapid Colorimetric Estimation of Acetate in Commercial Vinegar. PATRICIA L. LANG and ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——The modified basic ferric acetate qualitative test for acetate ion has been adapted to the quantitative estimation of that anion in commercial vinegars. A 5-ml sample of centrifuged vinegar is roughly neutralized with ammonia, then diluted to 10 ml. A 5-drop (0.25-ml) portion of this prepared solution is treated with 5 drops of 25.0% ferric nitrate, diluted with 5 ml of water, mixed and allowed to stand for

2 minutes for color development. The red-brown color is compared at 430-450 nm with that from a single standard, similarly prepared from a 3.0 volume percent acetic acid solution. The solution absorbance is linear with concentration from 0.5 to 3.5 volume percent acetate and is stable for at least an hour after color development. Results for a variety of commercial vinegars generally agree with pH-potentiometric titration results within 2-3 relative percent. The colorimetric procedure requires less than 10 minutes for completion and is quite appropriate for high school laboratory operations in limited-time laboratory sessions with inexpensive equipment.

Isomerization of the 5- and 14- Positions of Δ^7-6-Oxo Steroids. JOHN MCCUNE and BAHMAN NASSIM, Department of Chemistry, Indiana University Southeast, New Albany, Indiana 47150 and JERRY R. DIAS, Department of Chemistry, University of Missouri-Kansas City, Kansas City, Missouri 64110.——Cholest-7-en-3β-ol-6-one acetate was synthesized from cholest-5, 7-dien-3β-ol in three steps. The 5- and 14- positions of the enone were then isomerized by two different methods, each showing a high degree of regiospecificity. One method employed an acidic catalyst, p-toluene sulfonic acid; the other a basic catalyst, potassium tertiary butoxide. The acid catalyzed reaction favored 14α and 14β epimers while the base catalyzed reaction selectively isomerized the 5- position. Synthesis, separation and spectral measurements of the isolated isomers will be discussed.



Mass Spectral Fragmentation of Novel Steroidal Ketones and Ketals. BAHMAN NASSIM, Department of Chemistry, Indiana University Southeast, New Albany, Indiana 47150 and PIERRE CRABBÉ, Division of Scientific Research and Higher Education, UNESCO, 7, Place de Fonteroy, 75700 Paris, France.——Electron impact induced fragmentation of several A-nor, A-nor-18-homo and A-nor-D-homo steroidal ketones and their synthetic precursors are examined and mechanistic interpretation of some of the processes involved in their molecular breakdown are presented. As has been described by Djerassi and co-workers, extrusion of C_3H_4O and C_3H_5O from D-ring and usually the expulsion of the alkyl group from the 13-position of 17-oxosteroids are initiated by a preliminary ionization of the 17-ketone. It will be shown that the integrity of this initial charge development is dependent on the existence and nature of other functional groups present in the molecule. Therefore, the abundance of ions generated from these ketones can vary in a wide range. In the 17-oxo-D-homo steroids, a similar loss of 13-alkyl is observed, but the two losses seen from the 5-membered 17-oxo-D-ring are replaced by losses of C_2H_3O and C_4H_7O from the 6-membered 17-oxo-D-ring. 13-Ethyl-17-oxo steroids, in addition to extrusion of 13-alkyl group, lose ethylene through a McLafferty rearrangement, initiated by ionization of 17-keto group. Among other things, structural requisite for elimination of $C_2H_4O_2$ from odd electron ketal ions and generation of acetylacetone from a b-diketone steroid derivative, via two consecutive McLafferty rearrangements, will be defined.

Evaluation of Fluorescent Membrane Probes as Potential Detectors of Resolved Amniotic Fluid Phospholipids. BARTH H. RAGATZ and GINA M. MODRAK, Fort Wayne Center for Medical Education, Indiana University School of Medicine, Fort Wayne, Indiana 46805.——We have evaluated ten fluorescent membrane probes as potential

detectors of important phospholipids [phosphatidyl choline (LEC), sphingomyelin (SPH), and phosphatidyl glycerol, (PG)] which can be separated by thin layer chromatography from organic solvent extracts of human amniotic fluid. Detection of these compounds remains important in the assessment of fetal lung development.

We have evaluated the following parameters associated with these fluorescent sprays: sensitivity, color, stability, linearity of response, and limit of compound detection. Considering all these parameters, we have determined that 1-anilino-8-naphthalene sulfonate is the most useful fluorescent compound for this purpose. Other probes with some desirable characteristics are 5-dimethylamino-1-naphthalenesulfonyl-N-phosphatidyl ethanolamine and N-(5-dimethylamino-1-1-naphthalenesulfonyl)-L-α-phosphatidyl ethanolamine. Among the probes which are of no value in the present application are 5-carboxyfluorescein, 6-carboxyfluorescein, and 3-azido-2,7-naphthalene disulfonate (which must be photochemicaly activated and is quite unstable).

Hydrolysis of the Adenine Nucleotides, AMP and ADP, and Selected Purine and Phosphate Modified Analogs, BARTH H. RAGATZ and GINA M. MODRAK, Fort Wayne Center for Medical Education, Indiana University School of Medicine, Fort Wayne, Indiana 46805.——Using a Varian 5000 high pressure liquid chromatograph, we have determined the susceptibility to metal ion catalyzed hydrolysis of the following compounds: adenosine-5′-monophosphate (AMP); adenosine-5′-diphosphate (ADP); 1, N^6 etheno AMP (E-AMP); 1, N^6 etheno ADP (E-ADP); N^6 (γ, γ-dimethylallyl) ADP (DMA-ADP);α,β-methylene ADP (m-ADP); and adenosine-5′-phosphoramidate (AMP-NH_2).

At 56°C in pH5.0 sodium acetate buffer, 0.1*M*, with metal ion present in excess of the nucleotide, we have observed the following;

a) Virtually no ADP or AMP hydrolysis occurs over a six hour period in metal ion free-or Cu^{++} containing solutions. Dramatic hydrolysis (AMP ADP) occurs when Cu^{++} is present.

b) Cu^{++} catalyzed hydrolysis of E-ADP progresses more slowly than hydrolysis of ADP, whereas E-AMP is not hydrolyzed under present conditions.

c) The Cu^{++} catalyzed hydrolysis of DMA-ADP is comparable to that of ADP.

d) With the phosphate modified analogs, m-ADP and AMP-NH_2, hydrolysis does not occur under the stated conditions.

We conclude that charge distribution and size of substituents attached to the purine ring are both important determinants of the rates of hydrolysis of ADP-like compounds. Furthermore, phosphonate or phosphoramidate linkages are considerably more stable to hydrolysis at pH5 and 56°C than the corresponding diphosphate.

The Synthesis and Study of Functionalized Phosphines: Phosphine-nitrile and Phosphine-amine Ligands with Long Spacer Chains. PATRICK J. SELBY and BRUCE N. STORHOFF, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——A series of mono- and bidentate phosphines which also contain nitrile or amine groups have been synthesized and subsequently used to prepare metal complexes. Monodentate phosphine-nitrile ligands of the type $Ph_2P(CH_2)_nCN$ (n = 1,3,4,10) were obtained by reducing (Ph_2SiH_2) the Arbuzov products ($Ph_2POC_2H_5$ + $X(CH_2)_nCN$). Bidentate phosphine-nitrile ligands were obtained from $[Ph_2P(CH_2)_3P(Ph)]^-$ and $X(CH_2)_nCN$ (n = 4,10). The nitrile groups in these ligands were reduced to amines by AlH_3, $LiAlH_4$, or $BH_3 \cdot THF$. These new functionalized phosphines have been characterized by multinuclear nmr studies of the free ligands and of metal derivatives. A tungsten complex of the stoichiometry $W(CO)_4L$ ($L = Ph_2P(CH_2)_3P(Ph)(CH_2)_{11}NH_2$) was attached

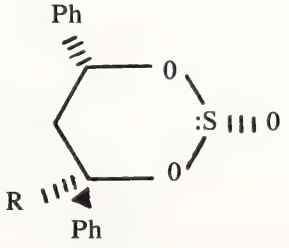
to aldehyde-functionalized glass beads. Fourier transform ir studies of the derivatized beads clearly showed the presence of the expected CO and CN stretching bands.

Detection of Trace Substances by Gas Chromatography—Mass Spectrometry. JOSEPH R. SIEFKER and BRADLEY K. YOWELL, Department of Chemistry, Indiana State University, Terre Haute, Indiana 47809.——Water samples were collected from selected wells in Vigo County and Parke County, from the Wabash River at Terre Haute, from the Terre Haute Wastewater Treatment Plant, and from a natural spring in Parke County. After concentration, trace substances were separated with gas chromatograph and introduced into a mass spectrometer. Mass spectra were obtained for numerous trace substances. Dibromochloromethane and 1-octadecanamine were possibly indicated in some wastewater samples. Other spectra gave no clear match with library reference spectra.

The Synthesis of a Crown Ether Designed to Exhibit Alkali Metal Cation Enhancement of Crown Ether Fluorescence. LYNN R. SOUSA, TODD E. TREHEARNE and ROBERT W. STEVENSON. Department of Chemistry, Ball State University, Muncie, Indiana 47306.——A bis(crown ether) is being synthesized that is likely to exhibit enhanced fluorescence in the presence of alkali metal cations. Such a "fluorogenic" crown ether could prove useful for the quantitative analysis of alkali metal cations such as K^+ or Na^+ or Li^+. The synthesis of the potential analytical reagent involves the production of azacrown ethers and their subsequent coupling to form the desired bis(crown ether)s. A progress report will be given.

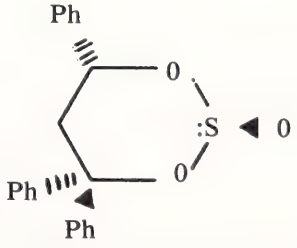
Sample Introduction Effects on the Excitation Mechanism in the Inductively Coupled Plasma. NORMAN SPROCH and JAMES P. RYBARCZYK, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——An arc/sparks emission spectrograph was locally adapted as a scanning monochromator/photomultiplier detection system for a Plasma Therm ICP. This system was utilized to measure changes in the excitation region of the ICP as the sample aerosol composition was altered. The vertical location of the various sample excitation zones of the ICP, from the preheat zone to the normal analytical zone, is directly related to aerosol composition. Aerosol modifications included smaller particle size, chemical composition, and desolvation effects. Effects of sample introduction changes on relative atom and ion populations also were studied.

Fragmentation and Isomerization of Trimethylene Sulfites. JEFFREY G. STACK and ROBERT J. OLSEN, Department of Chemistry, Wabash College, Crawfordsville, Indiana 47933.——Trimethylene sulfites 1 and 2 were found to undergo thermal and photochemical fragmentation reactions to produce olefins and carbonyl compounds.



1, R = H

2, R = Ph

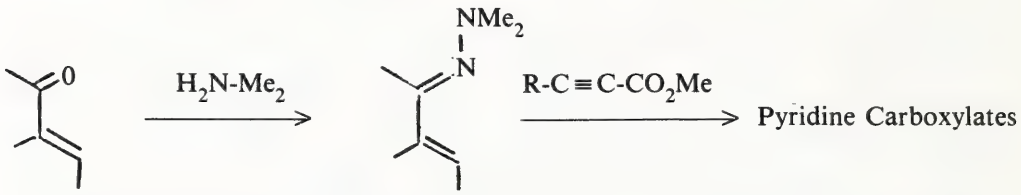


3

In the case of 2, the fragmentation occurs regioselectively to afford benzaldehyde and diphenylethylene. In addition, 2 undergoes an isomerization to produce the trans isomer 3.

Stereochemical assignments will be discussed and mechanisms for these reactions will be presented.

Pyridine Synthesis: Diels-Alder Reactions of 1-Azadienes with Acetylenic Carboxylates. LINDSAY S. STELZER and MOHAMMAD BEHFOROUZ, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——As part of the total synthesis of antibiotic lavendamycin, the synthesis of substituted pyridine carboxylates via Diels-Alder reactions were undertaken. A number of 1-N,N-dimethylamino-1-aza-1,3-dienes were prepared and their Diels-Alder additions with acetylenic carboxylates were studied:



The structures of products, yields, and other experimental details will be reported.

Digital Coding of Infrared Spectra and Computer File Searching with the TI-99/4 A.R. LEWIS VAN ATTA and ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306——A technique for digital coding of linear wavenumber presentation infrared spectra has been devised. The "specode" consists of seven numbers representing the two strongest absorption bands in the spectrum, as well as the strongest band in each of five spectral regions. Criteria for evaluation of spectral band significance are included; spectrum regions devoid of significant bands are appropriately designated. Specodes for known standard spectra are stored as data statements in a relatively simple TI-99/4A computer file programmed in TI Extended Basic. After an unknown compound spectrum is coded, the computer file, stored on cassette tape, may be quickly searched for probable matches. Positive identification is made by direct visual comparison of unknown spectra with the spectra whose specodes are matched by the computer file search. From 250 to 300 individual specodes may be stored on each side of a C-10 cassette tape, along with the search program.

Crystal and Molecular Structure of Octachlorostyrene, C_8Cl_8, a Great Lakes Pollutant

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and
RAY KAMINSKY and RONALD A. HITES,
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Introduction

Octachlorostyrene (OCS, C_8Cl_8) has been found in the environment with increasing frequency in recent years. Although clearly anthropogenic, it was of no commercial importance, and the reasons for its presence were unknown. It has now been determined (5) that most of the OCS in the Great Lakes results from the waste products of electrolytic chlorine production. This study was undertaken to confirm the identity of OCS and to provide detailed structural information for this pollutant.

Experimental

Nearly all crystals of OCS examined suffered from splitting or twinning to some extent. After examination of numerous samples, we finally utilized a crystal which, athough not split, was of questionable quality due to a large mosiac spread along one axis[1]. The crystal, with a maximum dimension of 0.14 mm, was affixed to a glass fiber using silicone grease and transferred to a Picker four-circle goniostat where it was cooled to -163 °C using a gas flow cooling system (2). The diffractometer and data reduction techniques used in this study have been described in detail elsewhere (3).

A systematic search of a limited hemisphere of reciprocal space located a set of diffraction maxima which were consistent with the monoclinic space group $P2_1/a$. Cell dimensions, as determined by a least squares fit of 34 reflections centered automatically, are: a = 16.706(7), b = 10.124(5), c = 7.498(2) Å, β = 86.12(2)° V = 1265.3(3) Å^3, and D_{calc} = 1.993 gm/cm^3 for Z = 4. Continuous theta-two theta scan data were collected for $6 \leq 2\Theta \leq 40°$ for all data with indicies +h, +k, ±l. Less than 5% of the data were observed in the range $40 < 2\Theta \leq 45°$, indicative of the poor quality of the crystal. A number total of 1578 reflections were collected and reduced to 1180 unique intensities for the structural analysis. Of these, 881 were considered observed on the basis of $I \geq \sigma(I)$, and were used in the final refinements.

The structure was solved by a combination of direct methods, an interactive Patterson interpreter (1), and Fourier techniques. All atoms were refined anisotropically, and the final cycles included an isotropic extinction parameter as well as the positional parameters and an overall scale factor. The goodness of fit for the final cycle was 1.853 and the residuals[2] were R(F) = 0.069 and Rw(F) = 0.047. A final difference Fourier was featureless, the largest peak being 0.45 e/Å^3. Final coordinates are listed in Table 1. Anisotropic thermal parameters, observed and calculated structure factors, and other details are available[3].

Discussion

An ORTEP (4) drawing of the molecule is shown in Figure 1, and bonded distances and angles are listed in Table 2. In general, all distances and angles are within the normally expected values. Two distinct planes in the molecule, one defined by C(1)-C(6), Cl(9)-Cl(13) and the other by C(6)-C(8), Cl(14)-Cl(16) are planar within ±0.08Å, with

TABLE 1: *Fractional Coordinates for C_8Cl_8. Numbers in parenthesis represent the estimated errors in the least significant digits.*

Atom	x	y	z
C(1)	1.0099(6)	.2801(13)	.2047(13)
C(2)	.9786(7)	.4027(16)	.2103(15)
C(3)	1.0199(10)	.5108(15)	.2672(16)
C(4)	1.0986(8)	.4913(13)	.3196(14)
C(5)	1.1321(6)	.3682(11)	.3068(13)
C(6)	1.0888(7)	.2586(11)	.2536(14)
C(7)	1.1246(7)	.1171(15)	.2677(16)
C(8)	1.1590(7)	.0680(14)	.1344(18)
Cl(9)	.9567(2)	.1417(4)	.1439(4)
Cl(10)	.8812(2)	.4244(5)	.1455(4)
Cl(11)	.9794(3)	.6650(4)	.2749(5)
Cl(12)	1.1530(2)	.6241(3)	.3873(4)
Cl(13)	1.2287(2)	.3450(3)	.3685(4)
Cl(14)	1.1106(2)	.0449(3)	.4743(4)
Cl(15)	1.1719(2)	.1405(3)	-.0717(3)
C(16)	1.2025(2)	-.0913(3)	.1446(5)

C(7) lying 0.17° below the C(1)-C(6) plane. The two planes intersect with a dihedral angle of 94.6°, due primarily to the steric interactions of the large chlorine atoms, as shown in the space filling model drawing (6) of Figure 2.

Acknowledgments

The authors wish to thank the Bloomington Academic Computing Services for a generous gift of computer time. We also thank Prof. Manuel Ballester of the Instituto de Quimica Organica Aplicada, Barcelona, Spain, for the OCS sample.

Notes

1. The width of omega scans varied from 0.5 to 1.8°.
2. Residuals are defined as $R(F) = \Sigma|F_o-F_c|/\Sigma|F_o|$ and $Rw(F) = \Sigma w|F_o-F_c|/\Sigma w|F_o|$.
3. Complete crystallographic details are available in microfiche form from the Chemistry Library, Indiana University, Bloomington, Indiana 47405. Request Molecular Structure Center Report 82037.

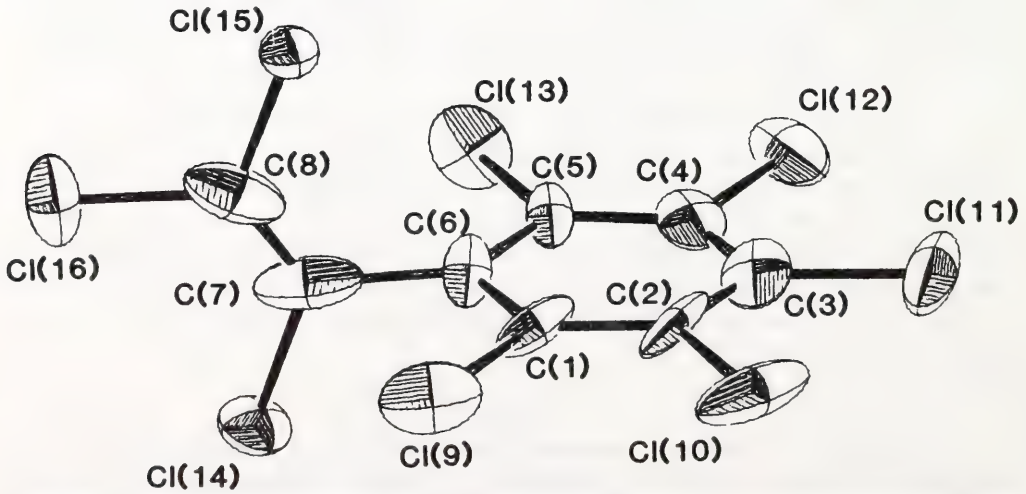

FIGURE 1. *ORTEP drawing of the C_8Cl_8 molecule showing the numbering scheme used in the tables.*

TABLE 2. *Bonded Distances (Ångstroms) and Angles (degrees) for C_8Cl_8.*

a) Distances

C(1)-C(2)	1.346(17)	C(1)-Cl(9)	1.735(13)
C(1)-C(6)	1.409(14)	C(2)-Cl(10)	1.743(12)
C(2)-C(3)	1.377(19)	C(3)-Cl(11)	1.701(15)
C(3)-C(4)	1.410(17)	C(4)-Cl(12)	1.719(13)
C(4)-C(5)	1.367(16)	C(5)-Cl(13)	1.724(10)
C(5)-C(6)	1.399(14)	C(7)-Cl(14)	1.715(13)
C(6)-C(7)	1.558(18)	C(8)-Cl(15)	1.712(13)
C(7)-C(8)	1.224(16)	C(8)-Cl(16)	1.773(15)

b) Angles

C(2)-C(1)-C(6)	120.1(12)	C(4)-C(5)-Cl(13)	119.5(10)
C(2)-C(1)-Cl(9)	123.2(10)	C(6)-C(5)-Cl(13)	118.7(8)
C(6)-C(1)-Cl(9)	116.6(10)	C(4)-C(5)-C(6)	121.7(10)
C(1)-C(2)-Cl(10)	118.4(13)	C(1)-C(6)-C(7)	122.0(11)
C(3)-C(2)-Cl(10)	118.9(12)	C(1)-C(6)-C(5)	117.6(10)
C(1)-C(2)-C(3)	122.7(12)	C(5)-C(6)-C(7)	120.1(9)
C(2)-C(3)-Cl(11)	122.2(13)	C(6)-C(7)-Cl(14)	115.0(9)
C(4)-C(3)-Cl(11)	119.7(13)	C(8)-C(7)-Cl(14)	126.3(13)
C(2)-C(3)-C(4)	118.1(12)	C(6)-C(7)-C(8)	118.7(12)
C(3)-C(4)-Cl(12)	119.6(12)	C(7)-C(8)-Cl(15)	125.9(13)
C(5)-C(4)-Cl(12)	120.7(11)	C(7)-C(8)-Cl(16)	120.4(11)
C(3)-C(4)-C(5)	119.6(12)	Cl(15)-C(8)-Cl(16)	113.7(9)

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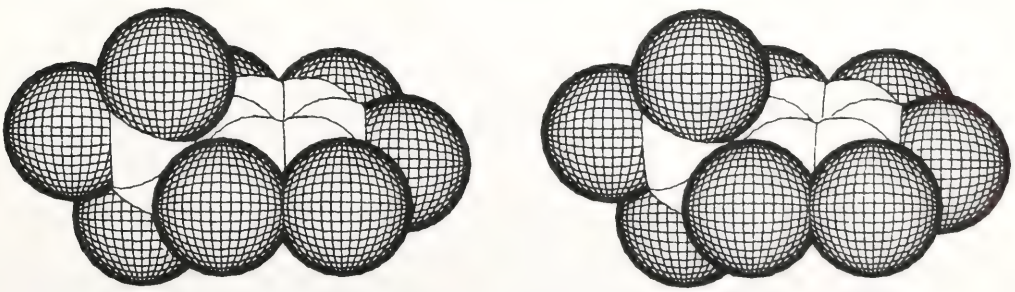

FIGURE 2. *Stereoscopic space filling model drawing of the C_8Cl_8 molecule.*

ECOLOGY

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ABSTRACTS

Genetic Variation in *Yucca glauca*. LORI ANN ASPRAY, Department of Biological Sciences, Purdue University, West Lafayette, Indiana, 47907.——The genetic variation of the monocot perennial, *Yecca glauca*, of the Central Grasslands of the United States was studied to determine which life history feature (breeding system, longevity, demography) influences the variation. The genetic variation for this outcrosser was assessed through starch gel electrophoresis. Three enzyme systems, alcohol dehydrogenase, phosphoglucose isomerase, and phosphoglucomutase were well resolved, and they were polymorphic. Many electromorphs formed various patterns in each system. Heterozygosity could not be identified for the populations due to the inability to determine loci; however, heterogeneity was noted within each of the eight sampled populations and individual capsule. The standard variance, F_{ST}, was calculated from electrophoretic data, and its value allows the conclusion that there is heterogeneity between populations. The F_{ST} value for *Y. glauca* is located between the values of biparental herbs and woody biparentals. It is possible that *Y. glauca*'s genetic variation is influenced by the breeding system.

The Egg Laying Process in the Micronesian Orb-weaving Spider, *Cyrtophora moluccensis* (Araneae: Araneidae). JAMES W. BERRY, Department of Zoology, Butler University, Indianapolis, Indiana 46208.——The female spider lives in a horizontal dome-shaped web up to one meter in diameter. The egg laying process starts about 10-12 PM and takes about four hours to complete. She first builds in the center of her web a horizontal, silken, shallow, concave disc about 10-15 mm in diameter. Building this disc takes about two hours. The white silk strands forming this disc are applied in a side-to-side motion at a rate of about one strand per second. When this inverted silken "dish" is completed, she fills it with a mass of about 1500 fertilized eggs in about 3 - 5 minutes. From beneath the egg mass, she begins applying silk over the eggs in a side-to-side motion, attaching the silk to the edges of the previously formed disc. When the eggs are completely covered with the white silk, she covers the entire egg case with greenish-colored silk. The egg case, attached horizontally to the center of the domed web, is cut free on all sides except one. This leaves the egg case hanging at 90° from the position in which it was formed. In as few as 10 days, a second egg case may be attached below the first one. A single female may produce as many as six egg cases. Intruding females have been observed adding egg cases to the one produced by the first female. Spiderlings leave the egg case in about 25 days. The female may remain with the egg case or cases long after the spiderlings leave the first egg case.

An Analysis of Disperal in *Peromyscus leucopus*. MARK HENRY and DAVID T. KROHNE, Department of Biology, Wabash College, Crawfordsville, Indiana 47933——The patterns of dispersal in the white footed deer mouse, *Peromyscus leucopus* were studied at Allee Woods Memorial Forest from May, 1980 to September, 1983. Two methods were used.

First, an extensive system of live-trapping grids identified dispersers by virtue of long distance moves within and between grids without any manipulation. In the second phase of the study dispersers were identified when they moved onto a removal grid from which all mice were removed at three week intervals. The two methods were in agreement on the characteristics of dispersers; adult males predominated. Dispersal was most common in the late summer and early fall but showed no proportional increase with density. The two methods differed in the frequency of dispersal. The removal study detected twice the number of dispersers as the unmanipulated system, perhaps because it artificially drew non-dispersers onto the removal grid.

Effects of Submersed Plants on Sediment Redox and Solute Levels. MARY L. JAYNES and STEPHEN R. CARPENTER, Department of Biology, University of Notre Dame, Notre Dame, Indiana 46556.——The chemistry of sediments colonized by vascular plants and mosses were compared with bare sediments in a soft-water acidic lake. Vascular vegetation consisted of *Isoetes braunii* and *Myriophyllum tenellum*, with total biomass averaging 24.88 g dry weight/m^2. *Drepanocladus exannulatus* dominated the moss vegetation, with total biomass averaging 59.39 g dry weight/m^2. All sampling sites were located at 3.6-4.0 m depth. Redox potentials (E_h) were significantly higher at vascular plant sites than at bare or moss-covered sites. Filterable phosphorus levels were lower in vascular-colonized sediments than in bare or moss-colonized sediments. No significant differences in filterable iron between sites were found. Results indicate that *Drepanocladus exannulatus* does not significantly alter sediment E_h and phosphorus levels from what is found in bare sediments, whereas the vascular macrophytes *Isoetes braunii* and *Myriophyllum tenellum* may effect these changes. Future field manipulations of these macrophytes and their sediments will seek to determine rates and mechanisms of sediment chemistry variations.

Changes in Population Characteristics of Yellow Perch in Indiana Waters of Lake Michigan, 1976-1981, Including Proportional Stock Density. THOMAS S. MCCOMISH, Department of Biology, Ball State University, Muncie, Indiana 47306.——Yellow perch (*Perca flavescens*) were sampled by trawling and gillnetting in Indiana waters of Lake Michigan from June through August, 1976-81, to monitor population characteristics. Rapid decreases in growth rate were observed comparing 1976 to 1981; males age I decreased 35mm, age II 61mm, age III 55mm, and age IV 44mm while females age I decreased 35mm, age II 55mm, age III 65mm, and age IV 51mm.

Gillnet catch curves were similar for all six years due to size selection. Trawl catch curves, however, revealed rapid growth occurred when recruitment to age I was low and the population was dominated by fish >100mm. In 1978 a strong 1977 year class dominated the population (fish < 100mm) and growth decreased in both 1978 and 1979. Continued rapid decreases in growth in 1980-81 were again due to strong 1979 and 1980 year classes and dominance of smaller fish (< 100mm) in the population.

Proportional stock density (PSD), the percent of quality size $\geq$ 200mm of the stock size $\geq$ 130mm, was applied to both gillnet and trawl catches. Gillnet PSD was very high at 80-90% in 1976-77 and declined to about 50-55% from 1978-81. Trawl PSD was greatest at about 25-35% in 1976-77 but decreased to 13% in 1978 and was only 3% by 1981.

Selectivity for larger fish limited usefullness of gillnet catch data but trawl catch data allowed adequate insight to changes in population structure and associated growth. A rapid decrease in growth rate and a shift in population structure toward dominance by smaller fish (< 100mm) occurred between 1976-81. The growth decreased was associated with high recruitment and strength of 1977, 1979, and 1980 year classes. Quality size fish, as measured by PSD, decreased dramatically after 1977 to lowest levels in 1981.

Trawl PSD appeared to be a better measure of actual population length-frequency shifts than gillnet PSD.

Computer-based Floristic Maps of the United States. JACK D. MCMILLEN and THEODORE J. CROVELLO, Department of Biology, University of Notre Dame, Notre Dame Indiana 46556.——We created floristic maps of the United States based on presence and absence of 177 tree species in 3049 counties of the counterminous United States. Counties were grouped into floristic regions using the SAS procedure FASTCLUS which produces nonoverlapping, nonhierarchical clusters from large datasets. The resultant maps are not totally objective since a number of subjective decisions affect the outcome. Subjective decisions include the species to use, number of regions and data transformation. We varied number of regions from 5 to 20 and used a number of transformations. Using simple presence/absence data, depauperate areas cluster rapidly. This results in one large region (of 20) encompassing the Great Plains and surrounding areas. At the opposite extreme is a transformation that produces distances similar to a Jaccard co efficient. This results in larger clusters of species rich areas and thus, the entire eastern deciduous forest becomes one of twenty regions. Use of different data transformations and numbers of clusters produce different maps. All of them concur, to some degree, with published floristic and vegetation maps and to physiographic areas. The decision as to which of the maps is best is still subjective, and should be based on the purpose of the study.

Do Amphibians Feed or Exploit Ponds? CRAIG E. NELSON, Department of Biology, Indiana University, Bloomington, Indiana 47405 and IBRAHIM H. JAAFAR, School of Biological Sciences, Universiti Sains Malaysia, Minden Penang, Malaysia.——The "successional energy exploitation" and "larval efficiency" models predict that acquatic-breeding amphibians with non-aquatic adults will exploit ponds by removing more energy as metamorphosed young than they transport as eggs. Two alternative frameworks, the "successional nutrient transport" and "limiting nutrient" models, focus on nutrient transport rather than energy transport and predict that amphibians will remove more nutrients than they transport in. The relative energy contents of eggs and newly metamorphosed young were determined for four *Ambystoma* and three *Rana* species. Comparisons with rates of survival to metamorphosis from other studies show that, contrary to the first two hypotheses, the energy transported into ponds as eggs often exceeds the energy removed as metamorphosed young. In-so-far as energy flow provides an estimate of nutrient flow, this suggests that the nutrient-based hypotheses will also often fail. A similar conclusion is suggested by the limited data available on nutrient-transport by pond-breeding amphibians. Thus the predictions from these four hypotheses are not universally true and appear not to be usually true: amphibians appear to feed ponds more often than they exploit them. Alternative models more compatible with our results are discussed.

A Model for the Interactions of a Tripartite Association. ROBERT J. REINSVOLD, Research Instructor, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907.——The tripartite association of a leguminous plant, a dinitrogen-fixing bacterium, and a mycorrhizal fungus is the norm for members of the Fabaceae. The purpose of this paper is to present a model which incorporates all the interactions of this complete system, i.e. the interactions between any two members and the effects of the environment.

Both *Rhizobium* (the dinitrogen-fixing bacterium) and the mycorrhizal fungus rely on the plant for carbohydrates and other organic compounds which serve as a source of carbon and energy. In the nodule, the bacterial enzyme nitrogenase chemically

reduces atmospheric dinitrogen (N_2) to ammonia (NH_3). The NH_3 is assimilated into nodular amino acids which are transported to the plant proper.

The mycorrhizal fungus enhances the growing conditions of the plant by 1) increasing the absorption of relatively immobile ions in the soil, e.g. P, Cu, Zn, and S and 2) providing a greater tolerance to adverse biotic and abiotic growing conditions.

The interaction between the two microbes appears to be more indirect, with the plant acting as an intermediary. The high phosphorus needs of the ATP metabolism in the nodules are satisfied by the greater uptake via the mycorrhizal hyphae which are in contact with the plant root. Nitrogen is fixed allowing the plant to grow and produce more foliage and leaf area. This in turn increases the total photosynthesis, supplying the photosynthate required to sustain both endosymbionts. Factors affecting photosynthesis however, also affect the activities of both the fungus and the bacterium, e.g. low light intensity has been shown to reduce plant growth, mycorrhizal development, and nodule activity. This tripartite association is a prime example of a finely tuned symbiotic system.

A Microcomputer Based System for Making Time Course Measurements of Dissolved Oxygen. DAVID F. SPENCER and HARRY W. JARRETT, III, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.—— Time course measurements of dissolved oxygen can be used to estimate rates of oxygen production or uptake by aquatic organisms. Advances in ion electrode technology have made such measurements feasible using a system composed of an oxygen electrode and a pH meter. A major disadvantage of this procedure is that it requires repeated measurements made over short time intervals. This obstacle has been overcome by interfacing the oxygen measuring system (Orion Model 901 Ionalyzer and Orion Model 92-05 Oxygen electrode) with a Commodore 64 microcomputer. The required circuitry is easy to construct and the components are inexpensive. A program written in BASIC monitors the electrode output at specified time intervals; prints the data; and calculates the slope, Y-intercept, and correlation coefficient. Data from oxygen consumption measurements using crayfish illustrate the usefulness of this method.

Limnological Assessment and Feasibility Study of Lakes of the Four Seasons. ARTHUR J. WHITE and W. H. SENFT, II, Department of Biology, Ball State University, Muncie, Indiana 47306.——The lakes of Lakes of the Four Seasons, a residential development in northwestern Indiana, have been identified as highly eutrophic lakes with severe water quality problems that impair their aesthetic and recreational value. With funding from the Property Owners Association, a diagnostic feasiblity study for the restoration of these lakes was conducted from December, 1981 through November, 1982. Mass water loading for this period to the system of interconnected lakes was estimated at 3.596×10^6 m^3 y^{-1}, with a resulting residence time 0.715 y. Areal phosphorus and nitrogen loadings were estimated at 0.4885 g m^{-2} y^{-1} and 12.234 g m^{-2} y^{-1} respectively. Stream flow input contributed 40% of the P and 54% of the N loading while direct runoff and subsurface seepage yielded 29% of the P and 17% of the N loading. Internal sources (sediments) accounted for 30% of P loading. The mean annual total P concentration for the system was 45.0 μg l^{-1} indicating a high degree of eutrophy. Mamagement strategies for the lakes focus upon cosmetic control of macrophyte and algal populations through chemical and/or mechanical treatments.

Effects of Flooding on Vegetation at Salamonie Reservoir

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Huntington College, Huntington, Indiana 46750.

Introduction

In estuaries, intertidal zones and freshwater marshes an early successional stage is maintained by fluctuations in water level. These fluctuations provide for rapid nutrient cycling due to aerobic decomposition during drawdown and subsequent release upon reflooding (12). Species with high rates of reproduction and growth are more likely to survive in these uncrowded early successional stages. In contrast, the selection pressure found in later stages of succession favors species with lower growth potential but better capabilities for survival in competitive circumstances (10). Some plant species, however, are capable of surviving periodic flooding due to physiological adaptations such as anaerobiosis (11), and morphological adaptations such as adventitious root systems and oxygen-channeling secondary root structures (9). Flood tolerant woody species, unlike most annuals invading a recently flooded site, usually require adaptations to inundation in order to survive (5,6,7,8).

The objective of this study was to evaluate variations in plant species in relation to flooding frequency. Salamonie Reservoir, the location of this study, appeared to be an opportune site because the impoundment had experienced very high water levels in the past two years. This study was done in conjunction with a small mammal reinvasion study (3).

Site Description

Salamonie Dam, completed in 1966, was built primarily for flood control purposes on the Salamonie River in the upper Wabash basin. The U. S. Army Corps of Engineers controls the working operations of the dam, including regulating water levels and flow rates. The Indiana Department of Natural Resources provides and regulates habitat maintenance, recreation facilities, and hunting and fishing. With minimum (winter) pool at 730 feet above sea level and summer pool at 755 feet, the normal annual variation in water level is 25 feet. The greatest possible variation between minimum and maximum (capacity) water levels is 63 feet, although no water level has come closer than 10 feet to this upper level. Because the water levels vary, a relatively large land area is periodically flooded and drained; and some higher land is flooded occasionally during periods of exceptionally high water.

Four sites on the north shore and one site on the south shore of the reservoir, approximately 1 to 1 1/2 miles apart from each other, were selected for study. Site #1, located 145 yds west of Huntington Co. Rd. 880W, is primarily a forested area with a 30 yd strip of abandoned farmland at the water's edge of the north shore. Site #2, located 125 yds east of Wabash Co. Rd. 750E, is composed of meadow at the water's edge, followed by an abandoned orchard and an old pasture located on the north shore. Site #3, located 95 yds east of Huntington Co. Rd. 700W, is composed of meadow at the water's edge, followed by an abandoned orchard and more meadowland. Site #4 located 210 yds west of State Rd. 105, is abandoned farmland (containing small *Acer negundo* seedlings at the highest elevations) located on the north shore. Site #5, located 160 yds southeast of the Dora boat ramp access road (an extension of

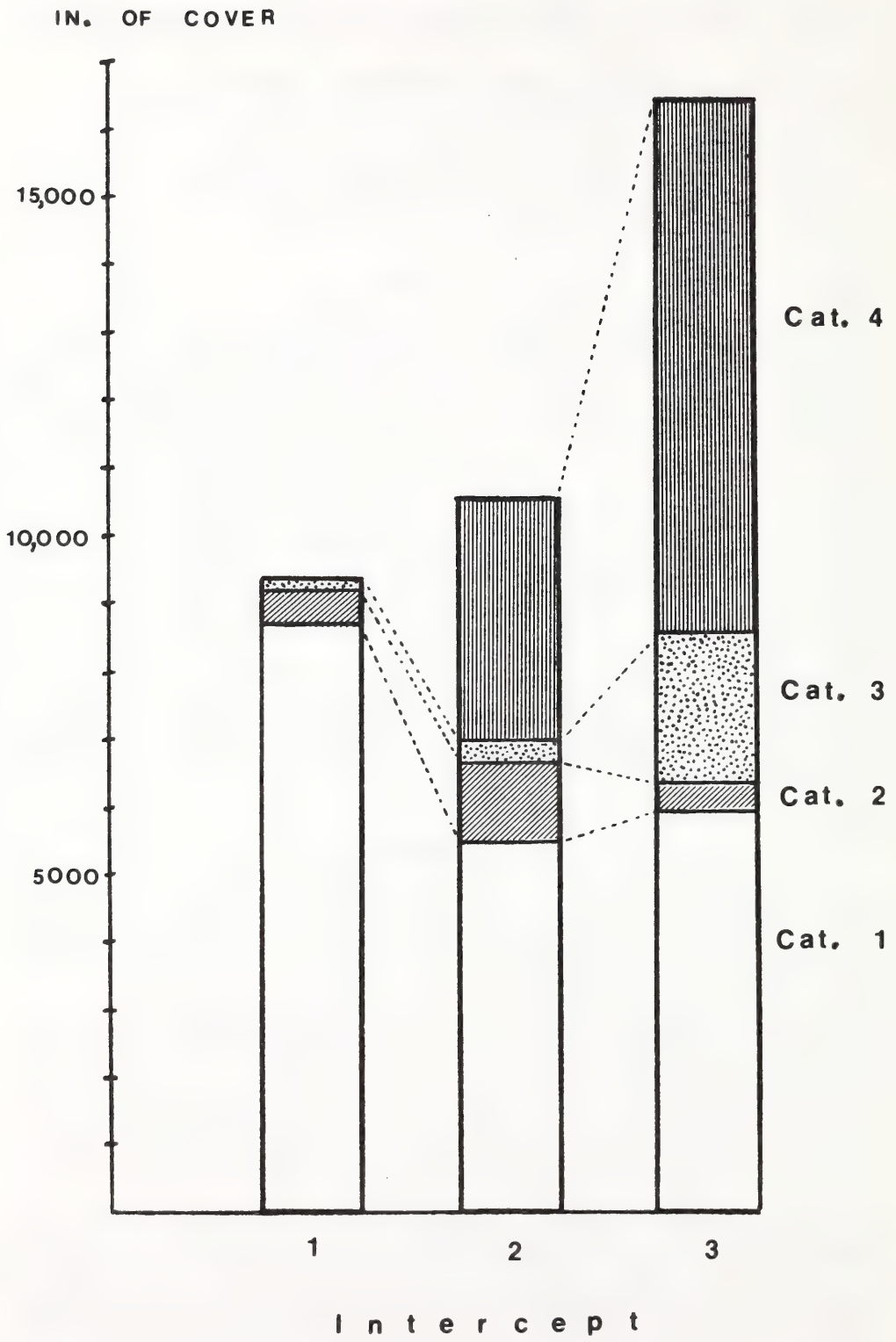

FIGURE 1. *Total cover of vegetation by category in combined transects #1, #2 and #3 at Salamonie Reservoir.*

Wabash Co. Rd. 250S), is a mature hardwood forest found on the south shore.

Materials and Methods

Using the line-intercept method of vegetation analysis, as described by Bauer (1943) and Eberhart (1978), three transects were laid out parallel to the shoreline at each site. These transects were located at intervals of 0 - 10 feet, 10 - 20 feet and over 20 feet above summer pool. Within each interval, random numbers were utilized for the placement of the transects. Total cover was determined for category I (forbs), II (woody shrubs and vines), III (trees under 12 feet tall) and IV (mature trees) species between May 25 (Site #1) and June 30 (Site #5) 1982. Sites were revisited to identify late blooming species.

Using a surveyor's level transit (Burger Model 504) and rod, the elevation of each transect above summer pool was determined. Using the records of daily water levels obtained from the Salamonie Reservoir Army Corps of Engineers, we determined the number of days each transect had been inundated during the last three growing seasons (April 15 - September 15).

Results

From the Army Corps of Engineers data on daily water levels it was found that the 0 - 10 ft level transects (transects #1) were inundated from 103 to 167 ($\bar{x}$ = 126) days during the growing seasons of 1980 - 82. Transects at the 10 - 20 ft level (transects #2) were inundated from 51 to 97 ($\bar{x}$ = 64) days, while transects at the 20 ft and above level (transects #3) were inundated from 0 to 48 ($\bar{x}$ = 18) days.

The total cover of the categories of plant species at each transect is shown in Figure 1. Category III and IV vegetation showed a marked decrease in total cover with increasing inundation frequency and were nearly absent in transect #1. Category II vegetation was twice as abundant in median transect #2 and in either the lowest and highest flooding frequencies. Category I vegetation exhibited the highest amount of total cover in the most heavily flooded transects.

Some of the category I vegetation showed significant trends in response to inundation (Figure 2). The greatest amount of cover in transect #1 was exhibited by *Ambrosia artemisiifolia*, while transect #2 was mostly composed of *Toxicodendron radicans* and transect #3 was mostly composed of *Bromus secalinus*. *T. radicans*, *Setaria viridis* and *Bidens vulgata* provided more cover in transects #1 and #2 and were much reduced in transect #3. *A. artemisiifolia* and *Polygonum pennsylvanicum* were abundant in transect #1 and greatly reduced in transects #2 and #3. *Daucus carota*, however, exhibited an inverse relationship in that its cover was extensive in transect #3, greatly reduced in transect #2, and nonexistent in transect #1. Plants present uniformly in all three transects, included *Erigeron philadelphicus* and *Dicanthelium lanuginosum*. *B. secalinus* and *Poa palustris*, though abundant in transect #3 were found exclusively in a meadow at Site #2.

Category II vegetation (Figure 3), particularly *Rosa multiflora* and *Vitis vulpina*, provided much more cover in transect #2 than in either of the other transects. *V. vulpina* was absent from transect #3.

Category III and IV vegetation trends are indicated in Figure 4. *Ulmus rubra* was the most dominant cover species in all of the transects. Total cover was greatest for category IV *U. rubra* at transect #2, while total cover for category II *U. rubra* was greatest in transect #3. Transect #1, though extremely low in tree cover, contained category III and IV *U. rubra*, with the exception of a small amount of category III *Salix interior*. In the much drier transect #3, category IV *U. rubra* shared cover dominance with several other tree species, namely *Acer saccharum*, *Crataegus* spp.,

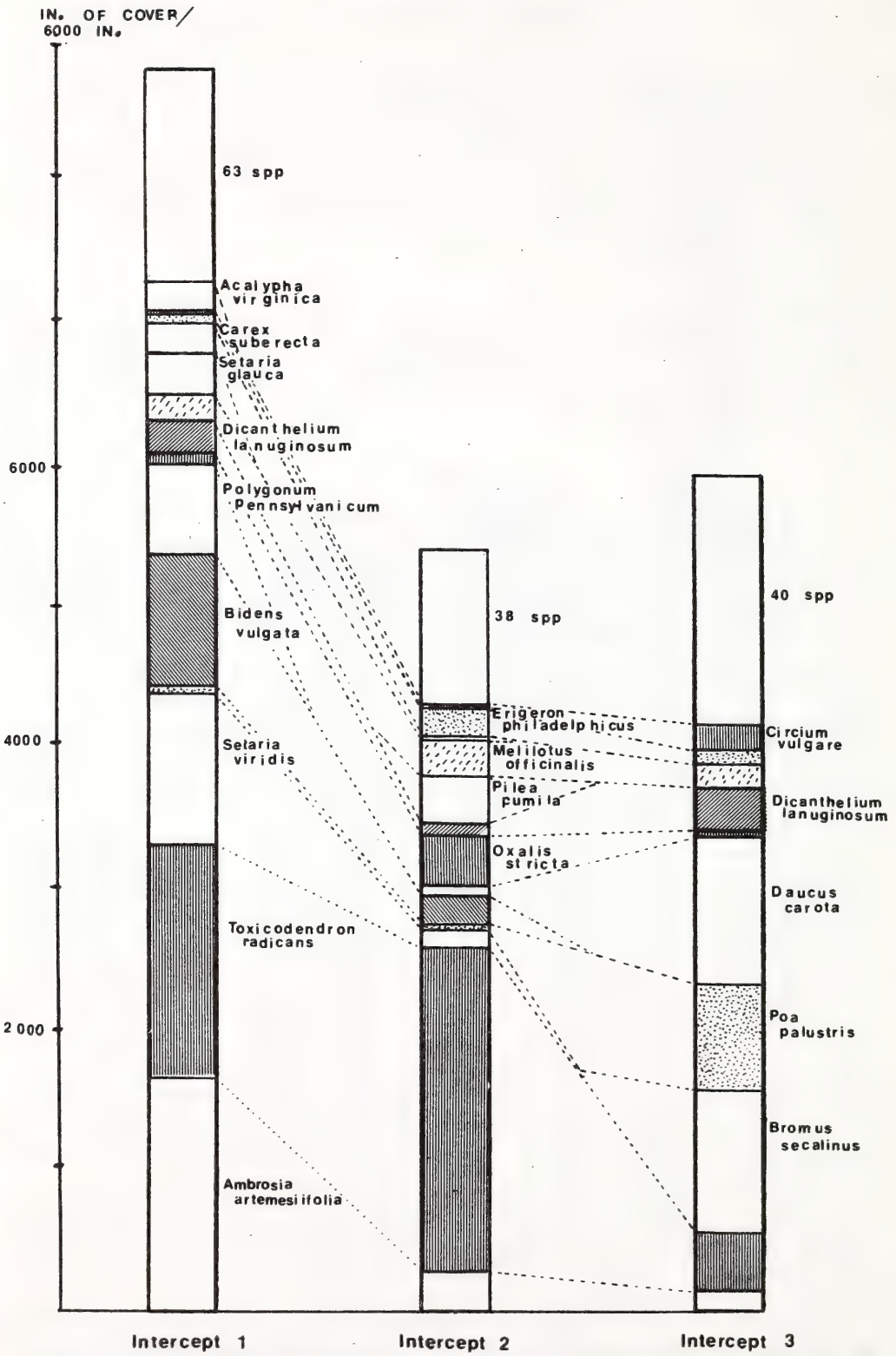

FIGURE 2. *Total cover of category I vegation species in combined transects #1, #2 and #3 at Salamonie Reservoir.*

Fraxinus americana, Quercus rubra and *Prunus serotina.* All of these species carry over into category III cover with the exception of *F. americana.* This can be con-

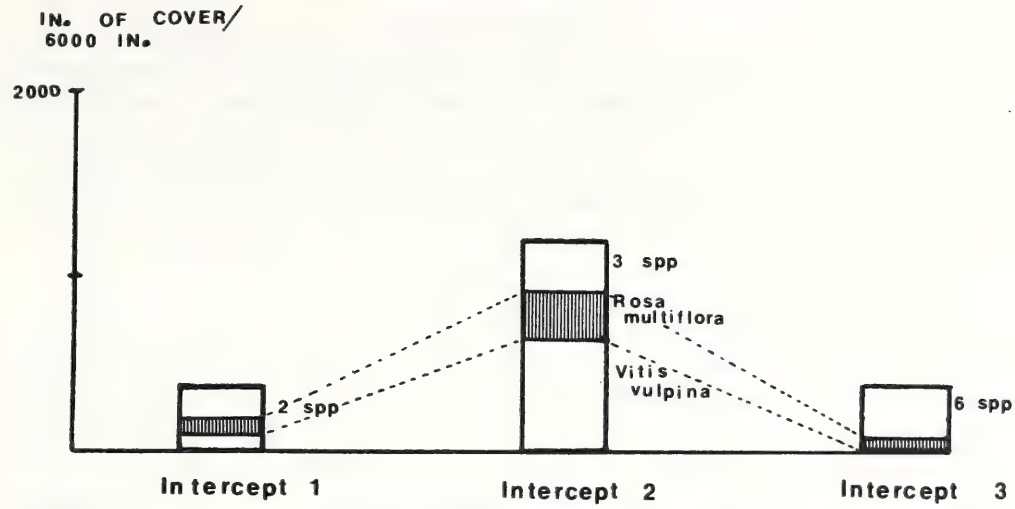

FIGURE 3. *Total cover of category II vegetation species in combined transects #1, #2 and #3 at Salamonie Reservoir.*

trasted with transects #1 and #2, in which both the number and evenness of tree species is reduced, as well as the amount of young category III trees.

Numerous category III and IV willow trees of the species *S. interior, S. cordata*

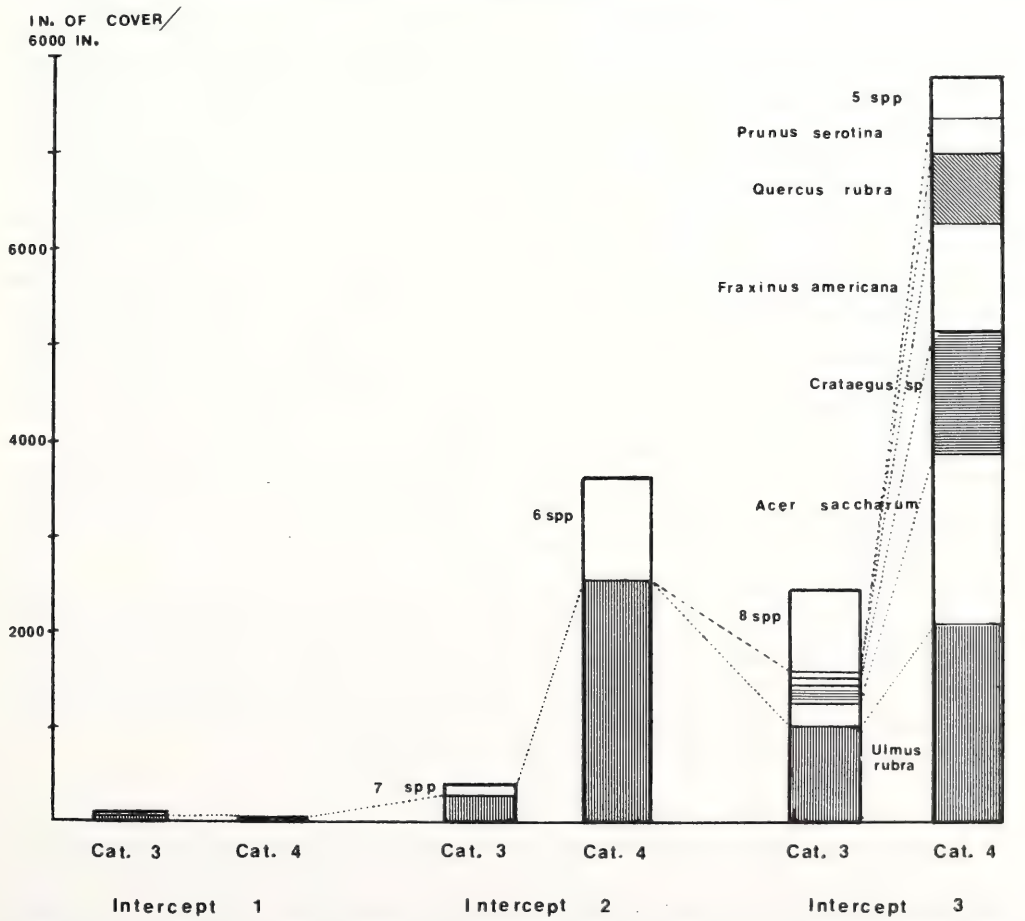

FIGURE 4. *Total cover of category III and IV vegetation species in combined transects #1, #2 and #3 at Salamonie Reservoir.*

and *S. amygdaloides*, as well as cottonwood (*Populus deltoides*) were growing on the study sites, but were not quantified due to their closeness to the edge of the summer pool. None of the transects passed through these species due to occasional short term flooding of the lowest elevations during sampling. Also present at the study sites was a band of standing dead trees including *A. saccharum, Robinia pseudoacacia, F. americana*, and *Crataegus* spp.. This band extended to approximately 15 ft above summer pool. The standing dead trees were not quantified.

Discussion

As indicated by the data, transect #1 was dominated by category I cover. *A. artemisiifolia, T. radicans, B. vulgata, S. viridis* and *P. pennsylvanicum* appeared to favor the early successional environment maintained by the highest flooding frequencies found in transect #1. Their reduced cover at the lower flooding frequencies may suggest an inability to compete with later successional species, or an inability to adapt to drier, less disturbed habitat typical of the later successional stages of a periodically flooded area. The constancy of *E. philadelphicus* and *D. lanuginosum* in all flooding frequencies may be a function of their adaptability or nonspecificity toward these environments.

Due to the widely varying habitats found at Salamonie Reservoir, transects #2 and #3 often had large differences in species composition between the study sites. These differences were much less pronounced and often absent in transect #1. At Salamonie Reservoir, the impact of high flooding frequencies appears to overshadow most of the other parameters that determine the species composition of an ecosystem. Caution must be exercized in applying this concept to all "wetland" ecosystems because changes in the floristic compositions also occur in response to destruction by predators and pathogens, to changes in physical or chemical conditions, to competition and allelopathy, and to species invasions (15). A long-term study at Salamonie could shed light on the interactive effects of flooding with other physical and biological parameters.

The tolerance of trees and shrubs to flooding at Salamonie is similar to studies in several other localities (5). *Salix* spp. and *Populus* spp., commonly referred to as "resistant" in previous studies, experience very little mortality in the Salamonie floods. Due to their adaptations toward inundation, they have been recommended often for the protection of periodically flooded banks (13,14). Brink (1954) observed that *Robinia pseudoacacia* suffered some damage from flooding in the Lower Fraser River Valley in British Columbia, but not a substantial mortality. Our observations, however, showed a widespread mortality of *Robinia* in the highest inundation levels. Since *Robinia* is commonly planted at Salamonie for wildlife forage purposes, it may be appropriate to avoid planting it in frequently flooded areas.

Ulmus rubra was more resistant to flooding than the other upland tree species found at Salamonie. This was not observed in previous studies, though flood resistance has been noted in *Ulmus americana* (5,6,7). Gill (1970) noted that *U. americana* had the ability to form adventitious roots in response to flooding. The authors suggest, in light of this data, that future studies should be performed regarding the morphological and physiological adaptations of *U. rubra* to flooding.

Acknowledgments

The authors wish to thank the Indiana Academy of Science for providing grant money for this study, and Neil Case, the property manager at Salamonie Reservoir State Recreation Area for his help and encouragement. Special thanks go to Dr. John Green at Huntington College and Dr. Lawrence Kapustka at Miami University for their criticism and advise on this project.

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The Historic and Present Distribution of Ruffed Grouse in Indiana

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Introduction

The ruffed grouse (*Bonasa umbellus* subspp.) is the most widely distributed gamebird in North America with a range extending from Georgia to Alaska (Aldrich and Duvall 1955). Ruffed grouse occur in a variety of habitats but are most abundant in early successional stages of hardwood forests. Its distribution in Indiana has been influenced by past and present land use, especially those affecting forested areas. This paper describes the past and present distribution of ruffed grouse in Indiana. Much of the work reported herein has been supported by funds under Federal Aid in Fish and Wildlife Restoration Act, Wildlife Research Project W-26-R, and Forest Wildlife Project W-27-D Indiana. Jennifer M. Eckensberger and Robert M. Platte are thanked for assistance in preparing this manuscript. John S. Castrale and Robert D. Feldt are thanked for their editorial comments.

Historic Distribution

Indiana was historically almost 90% forested with the tall grass prairie extending into several northwestern counties (Petty and Jackson 1966). Ruffed grouse reportedly inhabited all forested areas of the state (Barnes 1944) but historic records also included counties in the prairie region (Mumford 1957). Although historic records exist for only 58 counties, ruffed grouse probably occurred in all 92 counties of the state. Early records indicated two subspecies occurred, *B.u. mediana* in the northwestern third of the state and *B.u. monticola* in the lower two-thirds (Aldrich 1963).

Poplulations of ruffed grouse initially benefited from early settlement because scattered openings were created throughout the hardwood forest. Population densities of ruffed grouse in northern Indiana were considered similar to those of northern Ohio, Michigan, and Wisconsin (L.H. Haymond, in Butler 1897). As timberlands were over exploited and agricultural land use prevailed, grouse populations declined. Ruffed grouse occupied 58 counties by 1856 and were found in only 20 counties by 1897 (Butler 1897). In 1931, ruffed grouse occurred in only 12 counties (Leopold 1931).

During the 1930s and 1940s ruffed grouse were disappearing from the relatively flat and more fertile lands of northern Indiana because of increasing human impact on the land. Grouse populations in southern Indiana, however expanded during these "Great Depression" years as the hilly, nutrient-poor farmland was abandoned and allowed to revert to old field and early seral stages of forest succession. Ruffed grouse were given extra security as natural resource agencies began to purchase abandoned farmland for reforestation.

By the 1950s grouse had disappeared from northern Indiana but populations in southcentral Indiana had expanded to 18 counties with major concentrations occurring on publicly owned forests (Figure 1). Grouse densities were estimated to be 0.4-4.4 birds/40 ha (100 acres) (Mumford 1957).

As grouse began to repopulate their former range, restocking was initiated to accelerate recovery. From 1952-60, 180 wild-trapped birds purchased from the Sandhill Game Farm in Wisconsin were released in southcentral Indiana. These birds represented

FIGURE 1. *Distribution of ruffed grouse in 1951 (Mumford 1957).*

a different subspecies (*B.u. mediana*) than was native to the area (Aldrich 1963). This difference may have contributed to the limited success of these releases (Hamilton 1962a).

By 1961, ruffed grouse populations were again declining and their distribution was restricted to 14 counties (Figure 2) (Hamilton 1962b). However, isolated concen-

FIGURE 2. *Distribution of ruffed grouse in 1961 (Hamilton 1962b).*

trations of grouse were abundant enough to allow trapping and transplanting to other areas within the state. Between 1961 and 1982, 1,044 ruffed grouse were restocked at 25 release sites in 21 counties (Figure 3). Included were 126 grouse trapped in southern Michigan and released in northern Indiana. Beginning in 1965, grouse hunting was

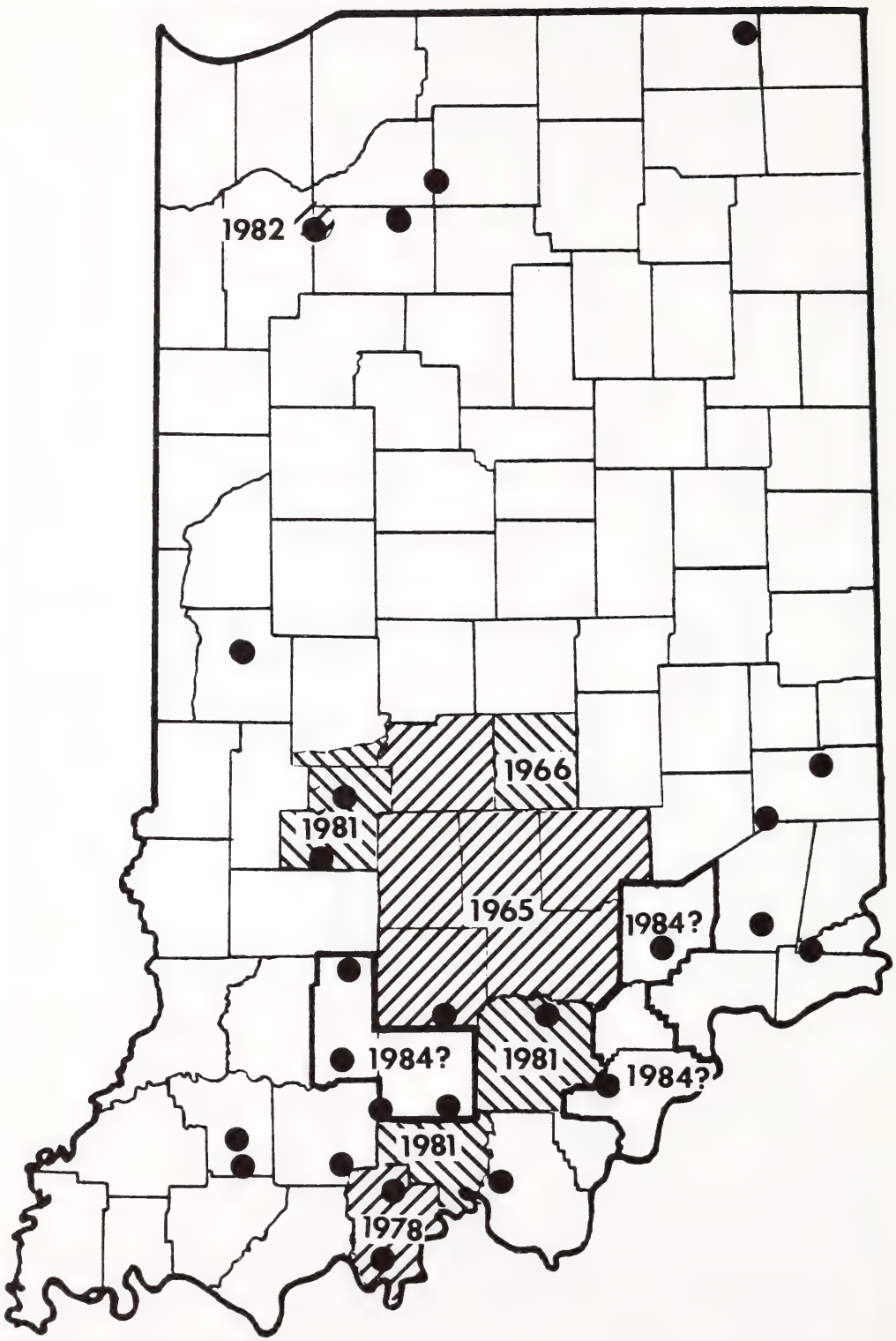

FIGURE 3. *Ruffed grouse release sites (●) from 1961 to 1982, and chronology of areas open to hunting since 1965 (slashed)*

legalized with a daily bag limit of 2 birds. Reports from 18 hunting seasons, indicate hunters averaged nearly 2 man-hours/bird flushed and 13 man-hours/bird bagged. Spring density estimates, based primarily on counts of drumming males (Gullion 1966), average about 4 birds/40 ha in main portions of the current hunting range.

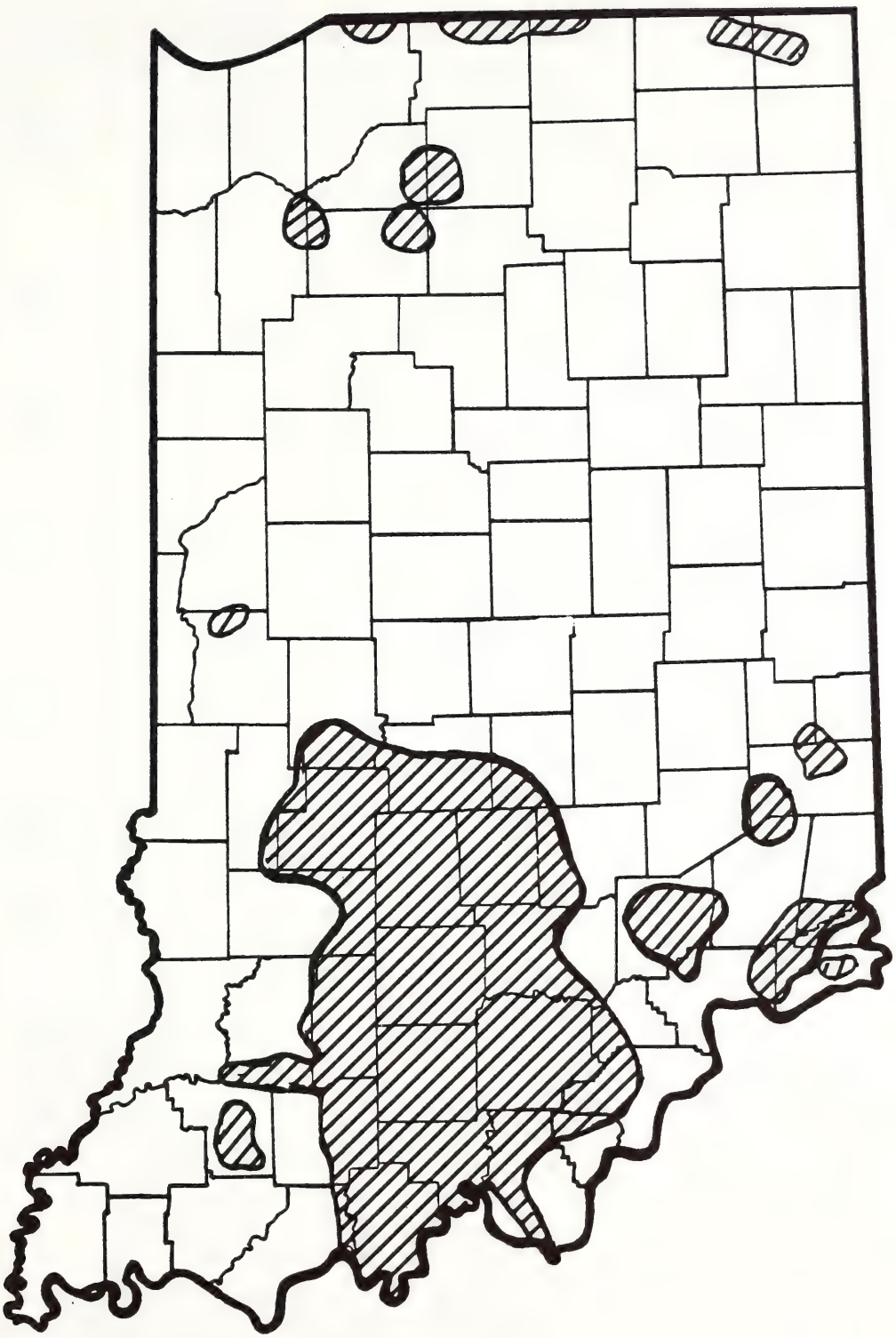

FIGURE 4. *Distribution of ruffed grouse in 1983.*

Present Distribution

In 1983, questionnaires sent to 168 Indiana Department of Natural Resources field personnel were examined to determine the current range of ruffed grouse. Respondents reported grouse observations made either personally or indirectly through

reliable public contacts within the last 5 years. Unique observations which may have represented grouse dispersing considerable distances in the fall (Godfrey and Marshall 1969) rather than actual populations were not included in mapping current occupied range. The present distribution includes 41 counties (Figure 4) and represents the largest distibution reported since 1856. The increased distribution is the result of restoration efforts and natural range expansion of grouse into areas of suitable habitat made possible by changes to more compatible land use.

Conclusions

The historic distribution of ruffed grouse has fluctuated with changes in land use, especially those affecting forest resources. The present distribution reflects the success of ruffed grouse restoration effort and natural range expansion into areas of suitable habitat. The future distribution of ruffed grouse in Indiana will depend, as it always has, on prevailing land use practices affecting habitats used by ruffed grouse.

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Effect of Flooding on Small Mammal Populations at Salamonie Lake

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Introduction

A number of studies have been made regarding the dispersal of small mammals, but there appear to be few studies of their reinvasion of recently flooded areas. Howard (1960), discussing a postulated "innate dispersal trait" in vertebrates, suggested that one advantage of such a trait would be the reinvasion of areas depopulated by a catastrophe such as flooding without first having to settle at the edges and only gradually moving inward. Flooding in northeastern Indiana in March, 1983, provided an opportunity to investigate and compare the movements of several species of shrews and rodents into recently flooded land. The present study was carried out by means of a snap trapping program between May 25 and July 2, 1982, at Salamonie Lake in Huntington and Wabash Counties. The study provides base-line data for any subsequent investigations which may be made in the same area.

Study Sites

Salamonie Dam, completed in 1966, was built primarily for flood control purposes on the Salamonie River in the upper Wabash basin in northeastern Indiana. At summer pool the lake covers 2860 acres. At flood control pool, 38 feet above summer pool, the lake would cover 9340 acres. The highest water since the completion of the dam, 32 feet above summer pool, occurred at Salamonie Lake on March 23 and 24, 1982. Water was back down to summer pool, 755 feet above sea level, by April 26, 1982.

Five study sites at intervals of 1 to 1 1/2 miles in a general east-west direction were chosen (Figure 1). At each site except site 3 a 4 x 25 grid of snap traps was laid out beginning at water's edge with the long axis perpendicular to the shoreline. At site 3 a shortened 4 x 23 grid was used. Sites 1 to 4 were on the north shore of Salamonie Lake, and site 5 was on the south shore. Vegetation analyses were also carried out at these sites, and are described in another paper (Arnold and Brown 1983, Proc. Ind. Acad. Sci., 93:153-159).

Site 1 was 145 yards (132 m) west of Huntington County road 800W, the Monument City Cemetery road. The first 30 m was abandoned farmland in early successional stage, and the remaining 210 m was hardwood forest.

Site 2 was 125 yards (114 m) east of Wabash County road 750E. The initial 40 m was meadow, the next 50 m was dominated by black cherry saplings mixed with mature dead trees, the next 50 m was an abandoned orchard, and the last 100 m was old pasture.

Site 3 was located 95 yards (87 m) west of Huntington County road 700W near the mouth of Little Majenica Creek. It crossed 60 m of meadow, 130 m of abandoned orchard, and 30 m of meadow.

Site 4 was 210 yards (192 m) west of Indiana state highway 105 on abandoned

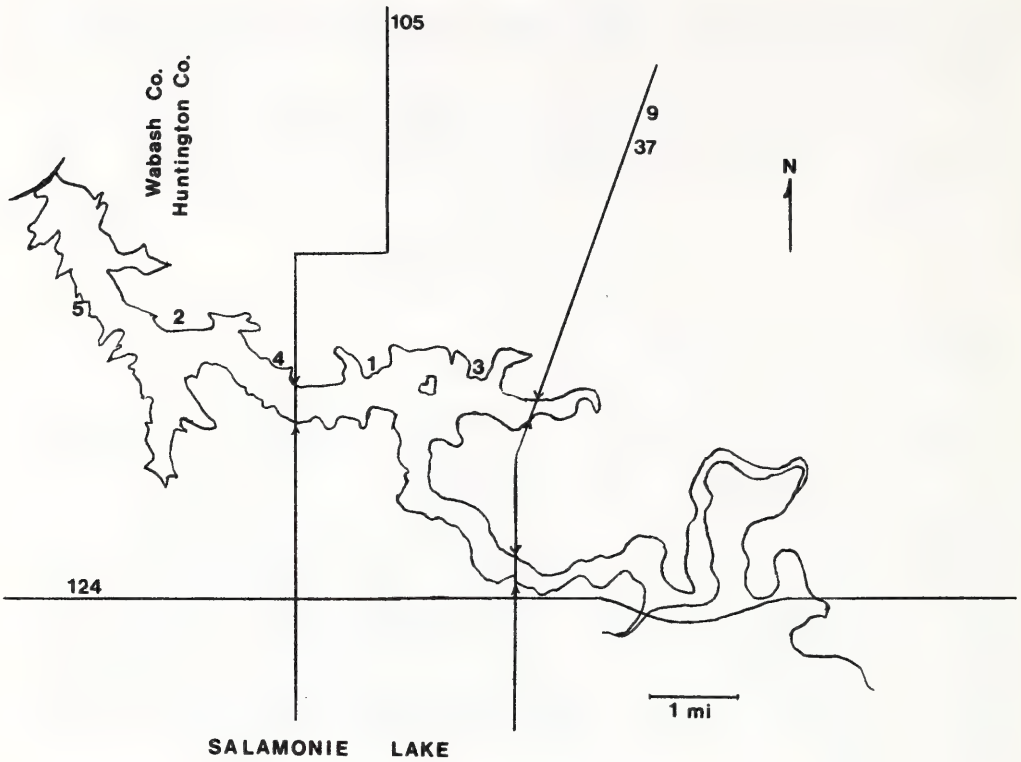

FIGURE 1. *Trap sites at Salamonie Lake, Indiana*

farmland. It was in an early successional stage although small *Acer negundo* were established in the upper quarter of the transect.

Site 5 was 160 yards (146 m) east of the Dora boat ramp road, which extends east of Wabash County road 250S. It was a mature hardwood forest.

Only 12% of the traps were on land which had not been under water.

Methods and Materials

Museum Special snap traps were baited with peanut butter and oatmeal. They were checked early each morning in order to minimize insect damage to trapped animals. Each site was trapped for 3 consecutive nights. The 4 x 25 grid of traps for 3 nights gave a total of 300 trap-nights (276 at site 3) for a grand total of 1476 trap-nights. Traps were set in straight lines with no effort to place them in runs or burrow openings. This would permit more reliable comparisons between this study and subsequent investigations at the same sites. All the animals caught were prepared as standard museum skin and skull mounts and were deposited in the reference collection in the Upper Wabash Regional Resource Center at Huntington College. Standard measurements and reproductive status were recorded. As a check on trappability of animals occurring on the study sites, two pitfall traps with drift fences were set at site 2 and left for one month. No species were trapped which were not caught also in the snap traps.

Data on daily water levels at the lake for 1982 was obtained from the U.S. Army Corps of Engineers office at Salamonie Dam. Each trap line was surveyed by means of a Burger model 504 transit-level to determine the height of each trap above current water levels. The contours of the trap lines are shown in Figure 2. From these data we calculated the following:

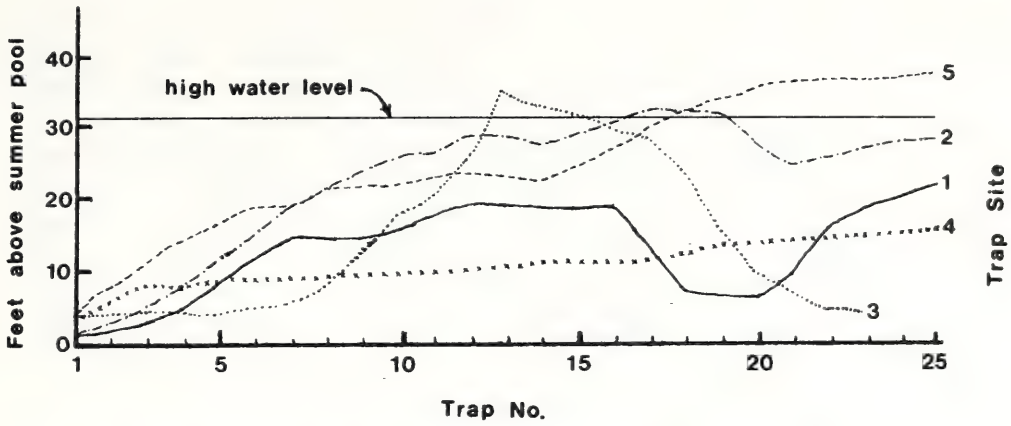

FIGURE 2. *Trap line contours and high water level.*

1. Height above summer pool of each trap.
2. Distance from each trap to the nearest unflooded land at the height of the flood.
3. Number of days from the time water had receded from a particular trap site to the time an animal was caught in that trap.

Schacht (1973) trapped small mammals at Salamonie Lake in 1970 and 1971, a period when there had been no flooding. We compared his trapping success with that of our study in 1982 after flooding had occurred by using a 2-tailed pair-wise test of hypotheses. For each species, the z value was calculated from the numbers taken per hundred trap nights in 1970-1971 period and in the 1982 period (Table 2).

Results

A total of 28 rodents (3 species) and 6 shrews (2 species) were caught in 1476 trap-nights. Results by species and trap sites are given in Table 1. The distance from point of capture to the nearest dry land at the height of flooding (3/23/82-3/24/82) as well as the time in days since water receded from the capture site are given in Figure 3.

Discussion

An examination of Figure 3 indicates that the three species of rodents reinvaded the flooded areas for relatively great distances as the water receded. Mumford and Whitaker (1982) suggested that *Microtus pennsylvanicus* are good swimmers, which may enable them to occupy wet places or areas that are temporarily flooded. Krebs *et al* (1969) found that *M. pennsylvanicus* in southern Indiana probably lives in surface nests during periods of soil saturation and local flooding. They found no evidence of substantial mortality in the trappable populations resulting from local flooding.

TABLE 1. *Trapping results by species and by trap site, 1982.*

Species	Trap Site					Total
	1	2	3	4	5	
Blarina brevicauda					1	1
Sorex cinereus		1			4	5
Peromyscus leucopus	1	3	2	1	1	8
Peromyscus maniculatus		2		8		10
Microtus pennsylvanicus		2	5	3		10
Total	1	8	7	12	6	34

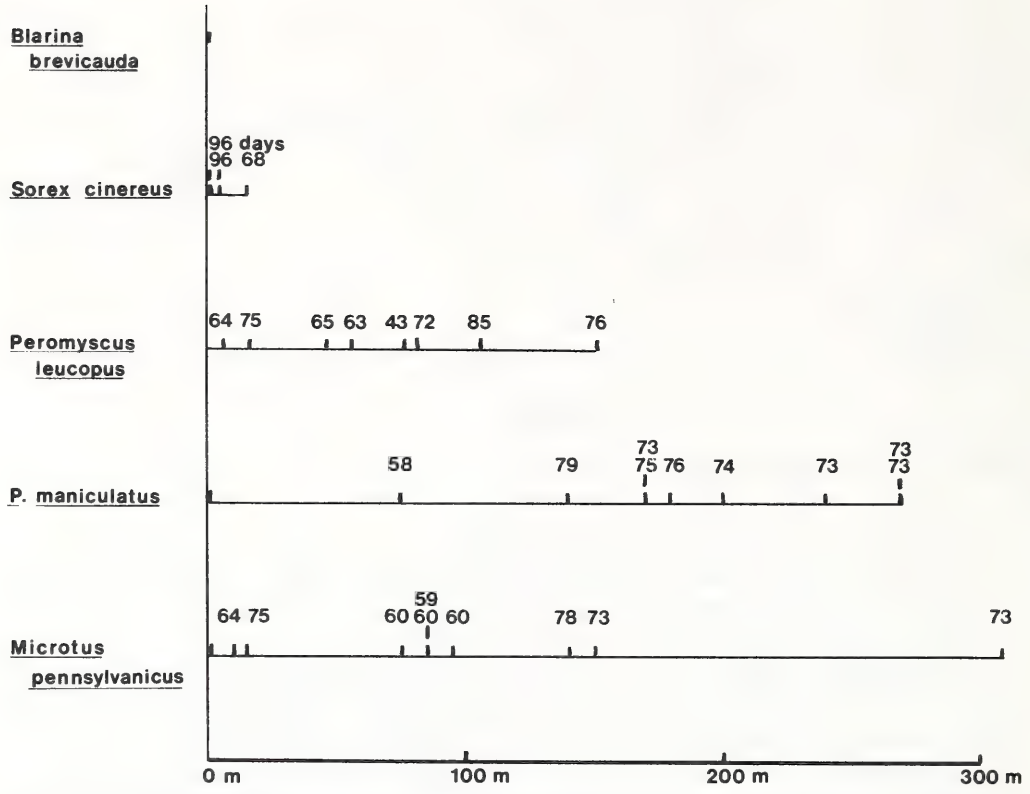

FIGURE 3. *Distance from point of capture to the nearest dry land at the height of flooding and the time in days since water receded from each capture site.*

In a study at Lake Opinicon, Ontario, Sheppe (1965) reported that many individuals of the species, *Peromyscus leucopus,* swam from one island to another or from an island to the mainland, usually only if the shore was visible. Distances ranged from 25 ft to 765 ft. Savidge (1973) noted that 3 of 9 *P. leucopus* which he displaced across a stream 3 to 4 m wide returned within 5 days. Mumford and Whitaker (1982) stated that during flood seasons, *P. leucopus* may live in trees. Our data provides no evidence that the species of rodents that we trapped at Salamonie Lake had to swim in order to escape from rising water or to disperse back into areas as the waters receded, but it does indicate that juveniles and adults do not appear to be severely affected by the type of flooding which occurred at Salamonie Lake in the spring of 1982.

Both *Sorex cinereus* and *Blarina brevicauda* can be found in moist habitats, and the latter species swims when necessary (Mumford and Whitaker, 1982). In the study of the effects of simulated rainfall on the least shrew, *Cryptotis parva,* Esher and Wolfe (1981) found that individuals occupying surface nests of their own construction survived without ill effects, but that individuals in underground burrows became soaked, came to the surface, and died. Although our study provided no direct evidence of mortality in the shrews due to flooding, it does indicate that they did not move back into recently flooded areas as quickly as the rodents. Sites 1 and 5 were very similar to each other in being predominantly hardwood forest. However, no shrews were caught at site 1, all of which had been under water, and at site 5 two shrews were captured above the flooded zone and the other three were trapped no further than 15 m into the area which had been flooded.

A comparison of numbers taken per 100 trap-nights was made between our study and that conducted by Schacht (1973) at Salamonie Lake in 1970-1972, a year in which

there was no flooding. Results of the comparison are shown in Table 2. When evaluating this comparison, differences in methodology should be noted. First, Schacht's trapping was carried out at a different time of the year with about 30% of his animals being trapped from February to April, and the remaining 70% from September to November, whereas our trapping was conducted from May to July. Second, Schacht's trapping was done primarily on the south shore of Salamonie Lake, and in some cases, relatively far from the shore (Schacht, 1983, personal communication). Third, Schacht trapped in a non-quantitative manner, placing his traps in runways or at burrow entrances where possible, while our trapping was done in fixed grids. Despite these differences in methodology, some interesting observations can be made. Trap success in the two periods was not significantly different for either *P. maniculatus* or *M. pennsylvanicus,* but trap success was significantly higher for the other three species in the earlier trapping program than in the later study which was carried out following flooding. There is not enough information to develop an explanation for the relatively low numbers of *P. leucopus* which we caught; however, the fact that we caught significantly fewer shrews than Schacht did for equal trap effort lends support to our conclusion that shrews do not move back into a flooded area as quickly as rodents. The reinvasion of land depopulated by flooding merits further investigation as such opportunities arise.

Acknowledgments

This research was supported in part by a grant from the Indiana Academy of Science. Equipment was provided by Huntington College. We also wish to express our thanks to Mr. Neil Case, Manager of Salamonie Reservoir, for his encouragement and help, to the personnel at the U.S. Army Corps of Engineers office at Salamonie Dam for giving us access to records of water levels at the lake, and to Dr. John Green for constructive criticism of the manuscript.

TABLE 2. *Comparison of numbers of animals taken per 100 trap-nights at Salamonie Lake in a season without flooding (Schacht, 1970-1971) with a season with flooding (Brown & Arnold, 1982).*

Species	Schacht			Brown & Arnold			Pair-wise hypothesis testing (α = .01)	
	Trap-nights	Nos. taken	Nos/100 TN	Trap-nights	Nos. taken	Nos./100 TN	z value	significant difference
Sorex cinereus	2478	28	1.13	1476	5	0.34	-2.89	Yes
Blarina brevicauda	2478	17	0.69	1476	1	0.07	-2.88	Yes
Peromyscus maniculatus	2478	12	0.48	1476	10	0.68	1.08	No
Peromyscus leucopus	2478	39	1.57	1476	8	0.54	-3.20	Yes
Microtus pennsylvanicus	2478	16	0.65	1476	10	0.68	0.15	No

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Wildlife Use of Cultivated Fields Set Aside under the Payment in Kind (PIK) Program

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The Payment In Kind (PIK) program was formulated by the United States Department of Agriculture (USDA) to reduce acreages of surplus agricultural crops: corn, wheat, sorghum, cotton, and rice. The primary objective was to decrease excess stores of these crops held by the federal government, and coupled with reduced production in 1983 due to diverted cropland, increase market prices of crops to the benefit of farmers. A farmer participating in the program agreed not to plant a specified acreage in exchange for surplus grain from the USDA in an amount based on a percentage of previous yields. The PIK program was administered by the Agricultural Stabilization and Conservation Service (ASCS) through their county offices. Restrictions on the use of PIK fields varied from county to county, but, generally, establishment of vegetation cover was required and weed control was encouraged. Grazing, haying, and cultivation were restricted, but exceptions could be obtained.

Although the primary purpose of the PIK program was to idle cropland for economic reasons, benefits for soil, water, and wildlife conservation were envisioned. Large scale programs that influence agricultural production and practices may have profound effects on these natural resources. Soil erosion, water quality, and populations of most farmland wildlife generally suffer from high intensity crop production. However, few studies are available that document impacts of cropland diversion programs on wildlife.

The purpose of this study was to determine relative wildlife value of lands entered in the PIK program by documenting use of PIK fields and conventional cornfields by birds and small mammals. Additionally, to better assess impacts of the PIK program on wildlife in Indiana, a statewide inspection of randomly selected fields was conducted. Taken together, these study approaches allow recommendations to be made regarding future set-aside programs to insure maximum benefits for farmland wildlife.

Corn and wheat were the primary crops included in the PIK program in Indiana. Figures compiled by the ASCS show 56.0% of 103,196 farms growing corn participating in the PIK program. The total corn base eligible for inclusion was 6,571,019 acres with 39.0% actually diverted from production. Grain sorghum is included in this amount, but it is a minor component because only 13,000 acres were planted in 1982 (Conservation Tillage Information Center 1983). The rate of participation of 50,827 farms growing wheat was 34.2% with 16.4% of the 1,287,680 acre wheat base actually withdrawn from production. In total, 2,774,377 acres of cropland were set aside under USDA programs in Indiana in 1983. This represents over 20% of the approximately 13 million acres of cropland in Indiana (Conservation Tillage Information Center 1983).

Study Area and Methods

Eight fields were selected to study bird and small mammal use. All were privately operated farms located in Scott County, southeastern Indiana (Figure 1). The topography is flat to moderately rolling with silt loam soils derived from glacial till.

Four study fields were conventional cornfields that had been planted to corn the previous year. Two of these fields had been disced the previous fall, 1 had been plowed,

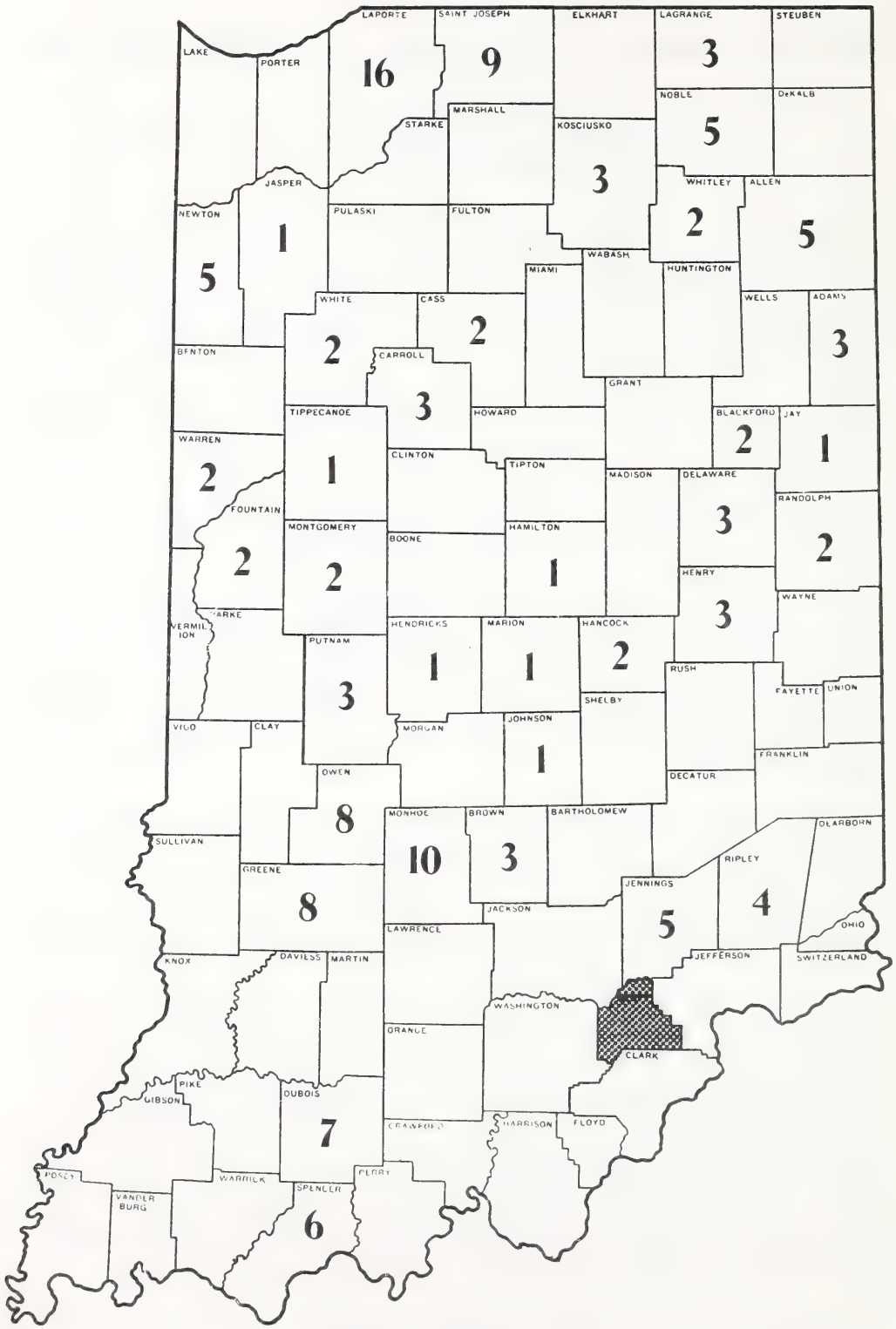

FIGURE 1. *Location of wildlife use study area (shaded) and number of PIK fields inspected in each Indiana county.*

and 1 had been chiselled. All were tilled in the spring prior to planting. Residue cover (ground cover) after planting averaged 3.5% (range 0.2-7.5%).

The 4 PIK fields had been under corn cultivation in 1982. All but 1 had cover crops (annual ryegrass, crown vetch, or winter wheat/yellow clover) planted the previous fall except for yellow clover which was sown in the spring. Crop residues remained untilled after fall harvest and volunteer annual and perennial forbs and grasses were common in all fields. Plant cover averaged 84.7% (range, 78.4-91.0%) in mid-June 1983.

Fields were trapped for small mammals during 1 of 2 sessions from 12-22 July 1983. Trapping sessions lasted 4 consecutive nights using snap traps baited with a peanut butter/rolled oats mixture. Traps were placed at 10-m intervals along straight line transects beginning at the edge of a field. Transects contained 25 traps, and 4 transects were placed in each cornfield and 2 placed in each PIK field. Traps were checked each morning, rebaited if necessary, and captured rodents collected.

Bird use was quantified by walking each field on 10 separate mornings in July and recording all birds observed. Birds flying overhead were ignored unless they appeared to be searching for prey (i.e., raptors) or actively foraging (i.e., barn swallows [*Hirundo rustica*]) directly above fields.

In order to evaluate the PIK program for wildlife on a statewide level, 11 wildlife biologists from the Indiana Department of Natural Resources (IDNR) were directed to randomly select 5 farms from ASCS offices in their districts. Biologists were provided with standardized forms and asked to inspect most or all of the PIK fields for each farm selected. Initial inspections were made 13-29 June to determine cover crops planted and to rate the cover present from poor to excellent for ground-nesting birds. Second visits were made a month later from 12 July-1 August to ascertain if fields had been disturbed. Procedures to survey diverted cropland were prescribed by the Midwest Association of Fish and Wildlife Agencies. Surveys conducted in 1973, 1974, and 1978 (Berner 1978) in Indiana allowed comparisons with the 1983 PIK data.

Statistical tests used to compare wildlife use consisted of Mann-Whitney tests with significance tested at $P = 0.05$.

Results and Discussion

Five species of small mammals were captured during 2,400 trap-nights of effort (Table 1). Deer mice (*Peromyscus maniculatus*) were the most commonly encountered species and occurred in all fields surveyed. Although deer mice were taken in greater average numbers in PIK fields than cornfields, no statistically significant differences

TABLE 1. *Capture rates (No. individuals/100 trap-nights) of small mammals from study fields in Scott County, Indiana, July 1983.*

Species	PIK	Corn
Deer mouse	4.38	1.50
House mouse	4.38	0.25
Prairie vole	0.63	0.00
White-footed mouse	0.25	0.00
Short-tailed shrew	0.00	0.06
Total	9.63	1.81
No. species/field	3.00	1.50
Species diversity (H')[a]	0.989	0.546
No. trap-nights	800	1,600

[a] $H' = -\Sigma p_i \ln p_i$.

could be shown. Capture rates varied considerably among fields, with figures ranging from 1.50 to 11.00 individuals/100 trap-nights for PIK fields and 0.75 to 2.75 for cornfields.

House mice (*Mus musculus*) were significantly more common in PIK fields than cornfields with capture rates in individual fields ranging from 2.0 to 7.5 individuals/100 trap-nights. In cornfields, house mice were uncommon and only captured in 1 of 4 cornfields. The remaining mammal species were represented by 5 or fewer individuals taken in all fields. Prairie voles (*Microtus ochrogaster*) occurred in 2 of 4 PIK fields but in no cornfields. White-footed mice (*Peromyscus leucopus*) also occurred only in 2 PIK fields. Short-tailed shrews (*Blarina brevicauda*) were represented by a single individual from a cornfield.

PIK fields supported significantly higher total densities of small mammals, with cornfields containing 19% of the individuals captured in PIK fields. PIK fields provided habitat for 4 small mammal species compared to 3 from cornfields, and individual PIK fields supported an average of 3.0 species, twice that of cornfields. Although species diversity of small mammals was low in these early successional habitats, values for PIK fields were almost double that of cornfields.

Deer mice and house mice are the most common species inhabiting cultivated fields in Indiana (Mumford and Whitaker 1982). Deer mouse populations usually reach higher densities where ground cover is reduced, and this is the only species able to persist under intensive cultivation. The data from this study, however, show that deer mouse can occur at high densities under high ground cover conditions. House mice, on the other hand, reach highest densities in cultivated fields with large amounts of residue, and my data demonstrate this relationship. PIK fields provided suitable habitat for prairie voles which prefer dry fields with a mixture of grasses and forbs. Voles should become more common if soil tillage does not occur. White-footed mice and short-tailed shrews prefer non-cultivated habitats and probably ventured into the study fields to search for food.

Thirty-one avian species were observed using study fields, but only 10 occurred on more than 5% of 80 visits (Table 2). Total bird occurrence and numbers of bird species noted in each field were significantly greater for PIK fields. Eight of the 10 most common birds made greater use of PIK fields than cornfields and differences

TABLE 2. *Occurrence of the most common birds on 10 visits to study fields in Scott County, Indiana, July 1983, Means are given followed by ranges in parentheses.*

	PIK	Corn	Statistical significance[a]
No. species detected	12.0 (10-12)	7.8 (5-9)	*
% visits on which birds			
were detected	100 (100)	68 (40-90)	*
Barn swallow	60 (30-80)	38 (0-70)	NS
Field sparrow	78 (60-100)	0 (0)	*
Indigo bunting	63 (60-70)	15 (10-20)	*
Mourning dove	40 (10-80)	10 (0-40)	NS
Song sparrow	60 (50-70)	5 (0-10)	*
Red-winged blackbird	55 (0-80)	20 (0-50)	NS
Northern bobwhite	48 (30-60)	0 (0)	*
Eastern meadowlark	28 (0-60)	0 (0)	NS
Killdeer	0 (0)	18 (0-50)	NS
Northern cardinal	5 (0-10)	8 (0-30)	NS

[a]NS ($P > 0.05$) or *($P < 0.05$) using Mann-Whitney tests.

were statistically signficant for 4 species. Only killdeer (*Charadrius vociferus*) and northern cardinals (*Cardinalis cardinalis*) occurred more often, although not significantly more, in cornfields.

Patterns of bird use of the study fields can best be explained by habitat requirements for nesting, feeding, and escape cover. Searches for nests were not conducted, but all birds listed in Table 2 probably nested in PIK fields except barn swallows, mourning doves (*Zenaida macroura*), northern cardinals, and killdeer. No birds were believed to nest in cornfields except possibly killdeer. This species requires bare ground or gravel-covered substrates for nesting and moist areas for foraging. Disturbances from tillage operations, however, make successful breeding uncertain. Field sparrows (*Spizella pusilla*), song sparrows (*Melospiza melodius*), northern bobwhites (*Colinus virginianus*), eastern meadowlarks (*Sturnella magna*), and rarely, mourning doves construct ground nests hidded by vegetation. Indigo buntings (*Passerina cyanea*), redwinged blackbirds (*Agelaius phoeniceus*), and field sparrows construct nets above the ground in erect forbs and shrubs. Northern cardinals require woody vegetation to support their nests. Barn swallows breed elsewhere because they build mud nests attached to vertical manmade structures such as bridge supports and barn walls. Mourning doves build nests above the ground in shurbs and trees unless these plants are limiting. PIK fields vary in their suitability for providing nesting habitats due to vegetation composition and structure. Eastern meadowlarks favor sod-forming grasses while the other species require a mixture of grasses, forbs, and semi-woody vegetation.

All birds in Table 2 used the study fields to obtain food. Most of the birds are highly insectivorous during the summer and feed primarily by gleaning arthropods from vegetation, ground residues, or the soil surface. Barn swallows actively pursue flying insects just above the vegetation. The greater occurrence of swallows in PIK fields suggests higher densities of flying insect populations. Mourning doves fed extensively in PIK fields and some cornfields, and this species is unique because of an exclusive diet of annual seeds and residual grains. Although low bird use of cultivated fields may be due to reduced food resources, the lack of sufficient cover in which to search for food may be more important. Low diversity of plant species and vegetative structure makes cultivated habitats less suitable.

Biologists inspected 137 PIK fields on 55 farms in 36 Indiana counties. The average field size was 14.5 ha and a total of 1991 ha was examined. The farms surveyed had diverted 60% of eligible acreage in the PIK program. Although PIK fields were required to be seeded, 21% of the acreage lacked a planted cover crop (Table 3). In most of these cases, farmers were unable to plant a cover crop due to unfavorable field conditions. Unseeded fields do not necessarily provide poor wildlife habitat if previous year's crop residue is present and volunteer vegetation is allowed to grow. Of the acreage without a cover crop, 58% was rated good-excellent as nesting cover. The relative area unseeded is low compared to previous surveys of diverted cropland in Indiana (Table 3).

TABLE 3. *Cover crop establishment (percent of acreage) in PIK fields and set-aside acres surveyed in Indiana. Data for previous years from Berner (1978).*

Year	Unseeded	Newly seeded	Established
1972	29.9	28.8	40.2
1973	15.1	10.1	74.8
1978	41.8	16.6	41.5
1983	21.3	65.6	13.1

TABLE 4. *Cover crops seeded on PIK fields surveyed in Indiana.*

Cover crop	Percent of fields (N = 137)	Percent of area (N = 1919 ha)
Legumes	55	55
Clovers	43	51
Alfalfa	9	9
Unspecified	6	2
Annual grasses	40	45
Oats	21	32
Wheat	14	7
Other[a]	7	8
Perennial grasses	18	23
Timothy	9	13
Other[b]	10	11
Buckwheat	<1	<1
Unseeded	23	21
Corn residue	15	11
Soybean residue	5	3
Fallow	3	8

[a]Includes sorghum, sudan grass, and rye.
[b]Includes orchard grass and bromegrass.

Most PIK acreage (66%) was newly seeded to cover crops indicating farmers were attempting to comply with PIK regulations, and the PIK program was successful in diverting fields from crop production. Fifty-four percent of the newly seeded acreage was rated good-excellent for ground-nesting birds. Only 13% of the PIK acreage was land that had an established perennial cover crop and 91% was rated good-excellent. If the PIK program for corn would have been extended beyond 1983, the amount with established cover would increase dramatically because most farmers seeded perennial plants on their PIK fields (Table 4). A mixture of plant species, usually a grass/legume combination, was seeded on 38% of the PIK acreage. Clover varieties and oats were commonly planted.

Overall, 56% of the PIK acreage inspected was rated good or excellent, which is the best rating in 4 years of surveys of diverted acres (Table 5). Improvement in this amount appears possible, however, by stricter monitoring of participants' land in the program. Reinspection of PIK fields in mid-summer, revealed that 74% of the acreage had been left undisturbed. Mowing was the most common form of distur-

TABLE 5. *Classification (percent of fields surveyed) of the quality of fields for nesting cover for PIK fields and set-aside acres surveyed in Indiana. Data for pervious years from Berner (1978).*

Year	Poor-fair	Good-excellent
1972	46.6	53.4
1973	44.7	55.3
1978	63.0	37.0
1983	44.5	55.5

bance and occurred on 23% of the land while a small percentage (3%) was disced or plowed. Most nesting birds should have been able to breed successfully by the end of July.

Conclusions and Recommendations

Wildlife use data presented in this paper demonstrate a high level of attractiveness of diverted cropland over conventionally tilled cornfields. Plant successional changes from a corn monoculture with large areas of bare soil to a stage dominated by annual forbs and grasses 1 year later are accompanied by a dramatic increase in diversity and population density of the avian and small mammal communities. Due to their mobility, birds respond more quickly than small mammals to these habitat changes. If fields were set aside for more than 1 year, vertebrate communities would continue to change in response to plant succession. Prairie voles would become a predominant species as perennial forbs and grasses become established and additional species of rodents and insectivores would colonize fields. Changes in the bird community would occur in response to changes in plant composition and vegetation structure. Both bird and mammal communities should become more diverse as the plant community becomes more complex and more microhabitats become available.

Statewide inspection of PIK fields revealed several shortcomings that upon correction would greatly enhance the value of diverted cropland for farmland wildlife. Soil cultivation should be strictly prohibited because this destroys wildlife habitat by burying vegetation and plant foods as well as causing direct mortality to sedentary animals. Grazing by livestock should also be restricted. Although usually not as destructive as tilling, grazing also results in reduced plant biomass, plant species diversity, and seed reserves as well as disrupted nesting attempts. Mowing should be prohibited during the nesting season (May through July) to allow successful reproduction. Although late summer mowing may be deemed necessary to prevent encroachment by woody plants and certain weed species, these habitat components are generally beneficial to wildlife and should be encouraged. Farmers entering a cropland diversion program should be required to establish a cover crop. Ideally, a grass/legume mixture should be seeded for maximum wildlife and soil conservation benefits. Weed control should be discouraged except for the most noxious weeds.

Agencies administering cropland diversion programs should inspect set aside fields, enforce restrictions, and penalize noncompliance to insure maximum benefits for wildlife. Programs should be formulated to last more than a single year to insure long-term benefits and to make more efficient use of cover crop plantings. Habitat for wintering wildlife would be provided by multiple year programs by preventing fall plowing and discing practices. Farmers should be encouraged to use minimum tillage to plant subsequent crops when lands are removed from a diversion program.

Acknowledgments

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Twenty-Five Years of Phytoplankton on the West Fork and Main Stem of the White River: 1958-1982

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Introduction

The phytoplankton of the White River has been studied for at least 50 years (1, 2, 4, 8, 9). These early studies were located around Indianapolis in conjunction with the publicly owned treatment works (POTW's). More recent studies have been in response to the environmental control movement of the 1970's and included intensive sampling around major wastewater sources, especially power generating stations (12). These studies, however, were usually limited to a small portion of the river over a relatively short time span. Some of these studies provided much detailed information about riverine flora in Central Indiana. In 1958 a monitoring effort was begun on the White River by the Indiana State Board of Health (ISBH), the objective of which was to provide long term general trends of the phytoplankton community. This presentation will discuss the results of the first 25 years of the program.

Study Area

Sampling stations were concentrated above and below major population centers such as Muncie, Anderson and Indianapolis (Figure 1). Sampling locations have been moved upstream, downstream, added or deleted, based on the needs and resources of the ISBH. Numerals following the station name describe the number of miles that station is located upstream from the mouth. Petersburg 48 and Hazelton 19 are "main stem" stations, located below the confluence of the East and West Forks of the White River.

Results and Discussion

Stations and years sampled are given in Figure 2. Traditional changes in sampling took place in January to retain the calendar year integrity of the program. Samples were collected monthly. In 1958 only 34 samples were gathered over the entire 350 mile stretch of the river. This number gradually grew to a peak of 106 samples in 1975, and 1976. In 1980 sampling was limited to only two stations, Muncie 319 and Petersburg 48. Winchester 350, Centerton 205 and Paragon 185 were sampled only two years, while Martinsville 194 and Edwardsport 80 were sampled during most of the 25 year history. Supportive data include as many as 30 chemical and physical parameters (6).

Exact speciation of the phytoplankton community for the entire period of record is impossible. The original bench sheets from 1958 to 1974 were lost and all that remains for this period are the major grouping values as published in the Annual Water Quality Reports (6). From 1975 to 1982 a more detailed evaluation of the phytoplankton community exists.

Martinsville 194 (Figure 3) had the most samples (226) and the longest period of record (20 years). Approximately 76% of the collections consisted of diatoms, ranging from a low of 58% in 1973 to a high of 93% in 1961. The most abundant genus was the centric diatom *Cyclotella. Navicula, Gomphonema* and *Synedra* were also dominant at times. The green algae was next in abundance at a 16% yearly average ranging

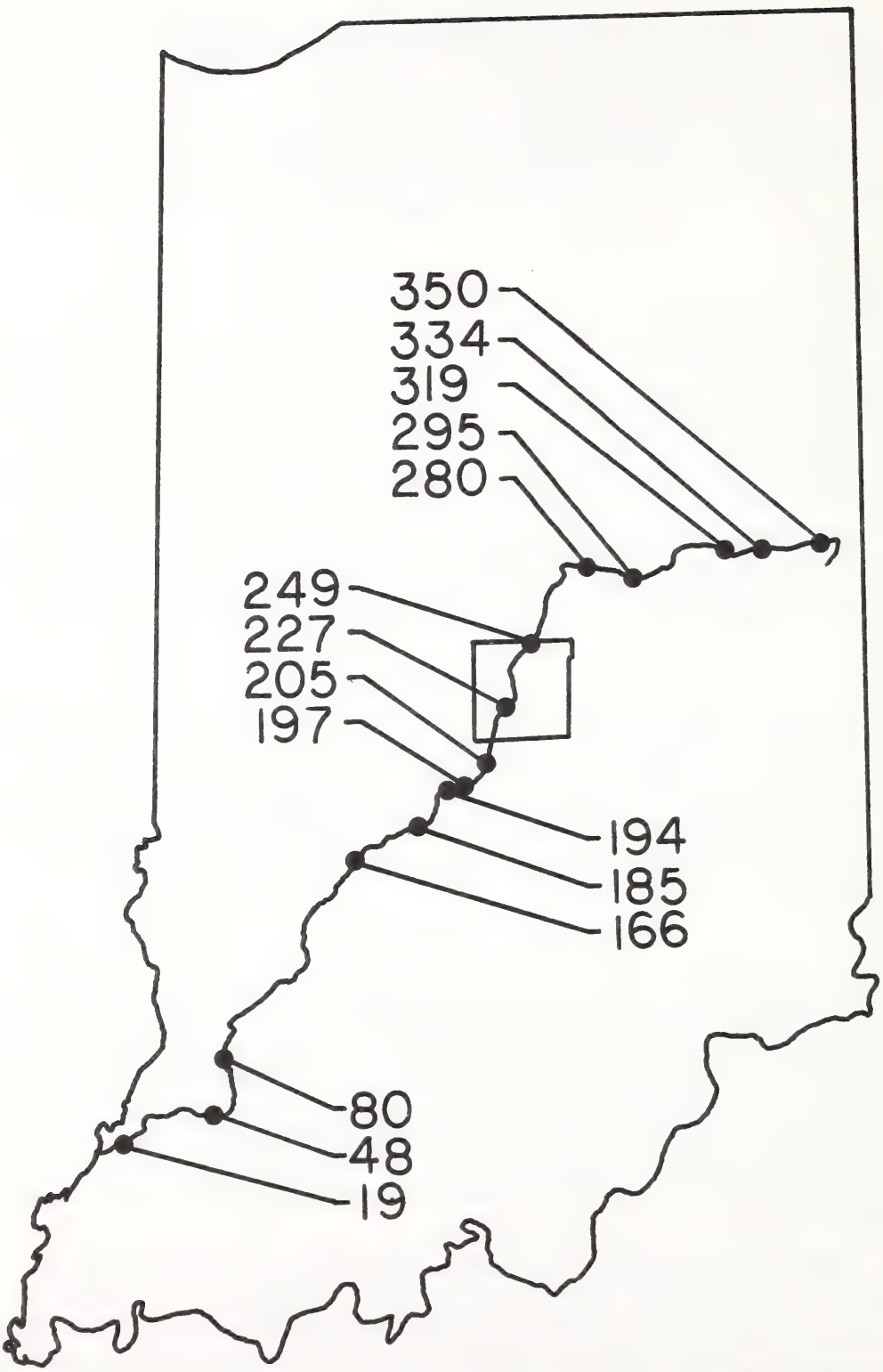

FIGURE 1. *Locations and river miles of the stations sampled on the White River during the period 1958-1982.*

from 1% in 1961 to 27% in 1972. *Scenedesmus* was the most abundant genus, but consisted of a number of unidentified species. No other green alga was consistently dominant during the study. About 2% of the total was blue-green algae with the re-

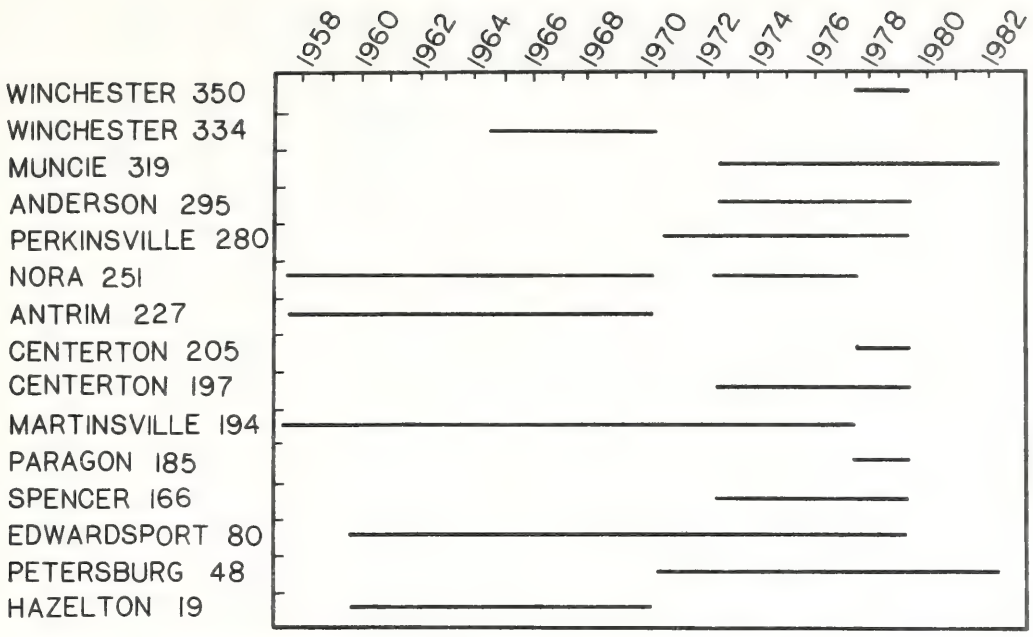

FIGURE 2. *Stations and years sampled for the period of study.*

mainder of the species, primarily flagellates, making up about 6% of the organisms found.

Because of the limited number of samples in a particular year, one or two samples can drastically alter a given mean. This is shown for the Martinsville data using total

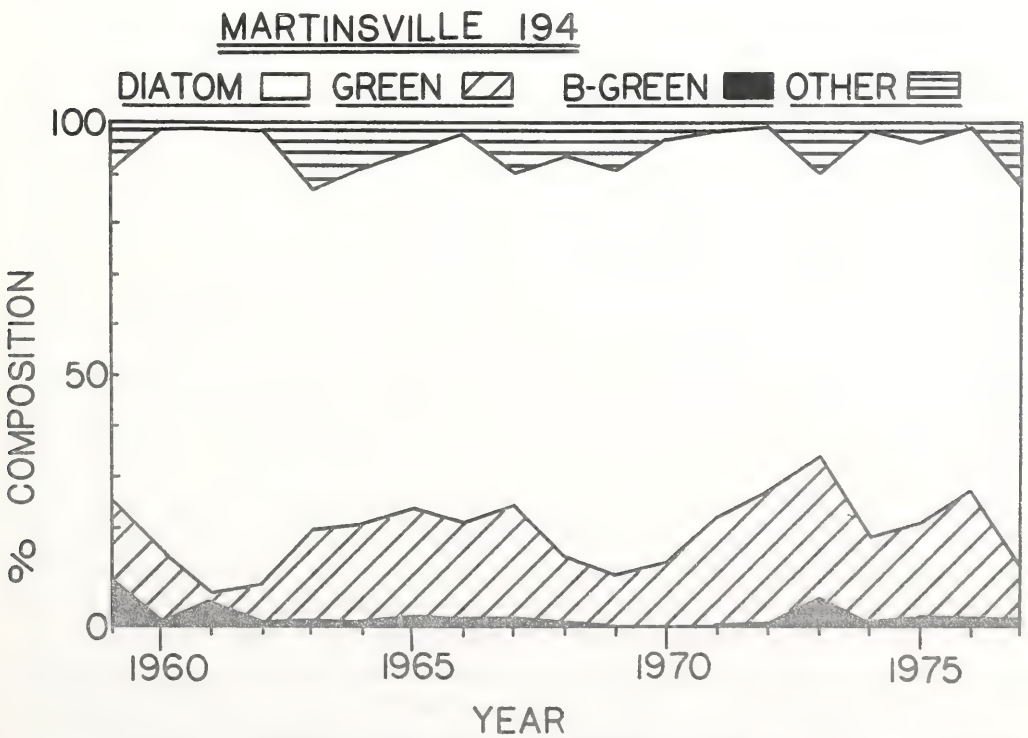

FIGURE 3. *Percent composition of major algae groups at the Martinsville 194 station from 1959-1977.*

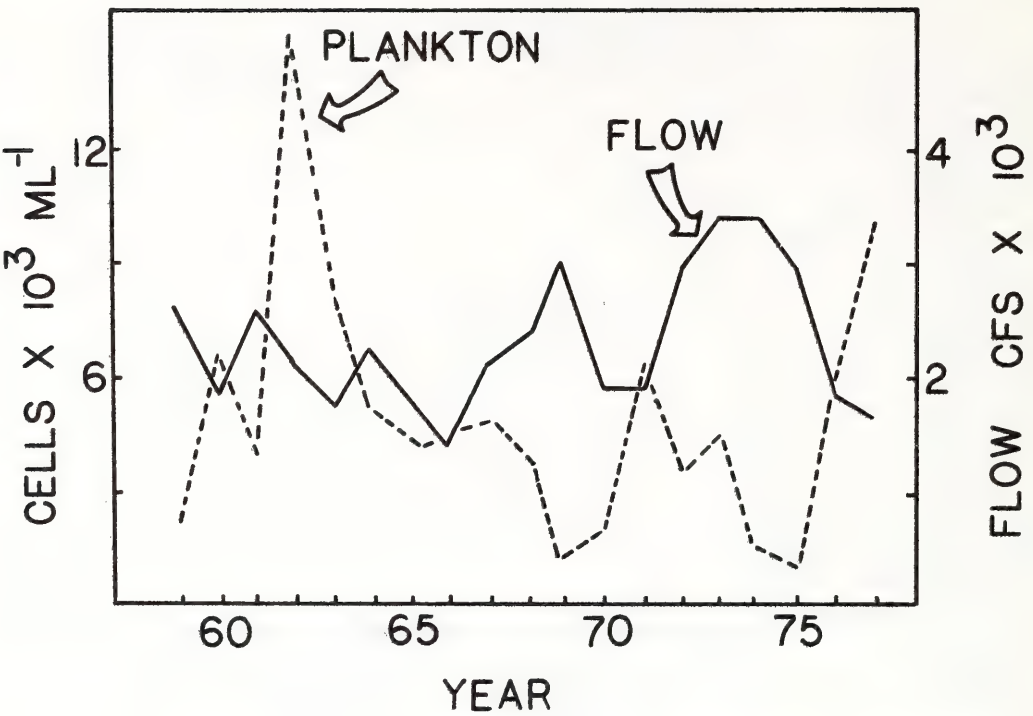

FIGURE 4. *Mean annual phytoplankton densities and flow discharge values at Martinsville 194 station from 1959-1977.*

cell counts with the mean annual averages (Figure 4). The May and June samples in 1962 were 52,610/ml and 49,000/ml respectively with a mean average for the year of 15,233/ml. This is in contrast to the mean yearly low of 1,038/ml in 1975.

This wide range of values cannot be fully explained. Nutrient levels, temperature, and light intensities are fundamental to algal growth (10). However, many of these variables in the White River appear to be directly related to flow. Annual mean discharge as measured at the USGS Gaging Station near Martinsville (11) provides additional information (Figure 4). Low mean phytoplankton densities correspond to high flow years 1959, 1961, 1968, 1969, 1972, 1973, 1974 and 1975. High phytoplankton densities were only found in 1960, 1962, 1963, 1971, and 1977 when flows were reduced. Maximum phytoplankton growth only appears when flow values are lower than approximately five times the $Q_{7,10}$ value. Phytoplankton densities as high as 200,000 cells/ml were found in some portions of the river (Edwardsport 80, August 1976).

The nutrient point source loading comes from many places along the river. The cities of Muncie, Anderson, and Indianapolis contribute the largest amounts. The two POTWs in Indianapolis (Belmont and Southport) alone discharge approximately 150 MGD treated wastewater to the White River (7). The phytoplankton populations appear to be reacting to this nutrient loading. Figure 5 shows a slight decline in plankton densities below Indianapolis, followed by an increase to a peak at Edwardsport 80, and a decline in Petersburg 48. Supportive phosphate and ammonia data indicate an immediate rise in concentration and a gradual decline back to "upstream" Indianapolis levels. Hynes'(5) representaton of a river system sustaining organic pollution (Figure 4) shows a close similarity to the White River system. Zones of clean water (1), organic degradation (2), active decomposition (3), recovery (4) and clean water (1) are indicated for phytoplankton densities, ammonia, and phosphate. Organic loadings from Indianapolis, therefore, are affecting the White River for a length of 150 miles according to Hynes' classification. Other classification schemes (3, 13) show similar results.

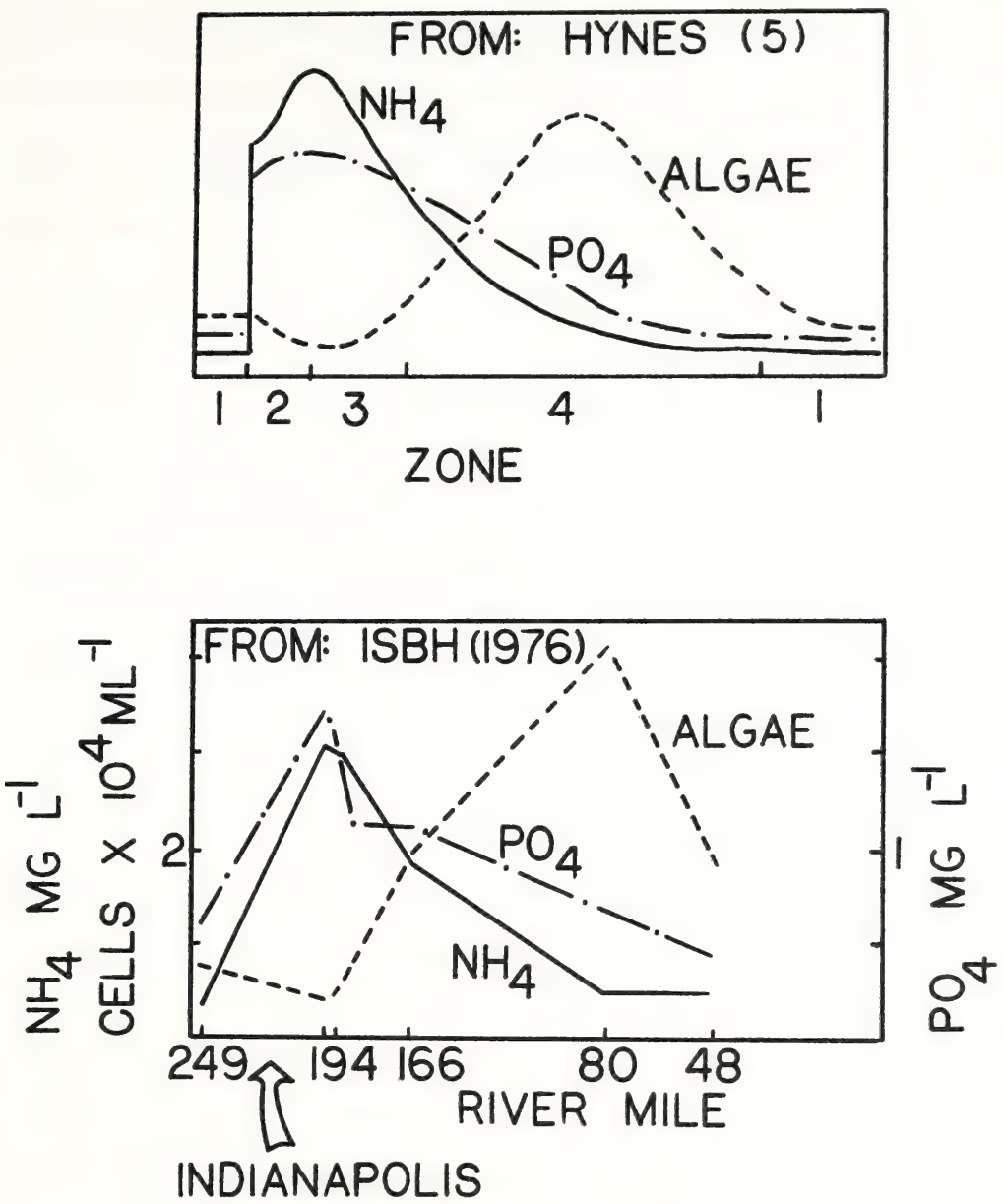

FIGURE 5. *1976 ISBH mean values for phytoplankton, ammonia, and phosphate from river mile 249 to 48. Also pictured is Hynes (5) representation of a river system undergoing organic degredation (see text).*

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Survey of the Woody Vegetation of the Kankakee Sand Area Section of Indiana and Illinois

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Introduction

The Kankakee Sand Area Section of the Grand Prairie Division (Schwegman, 1973) is located in northeastern Illinois and northwestern Indiana, with its best floristic development in Kankakee and Iroquois Counties, Illinois, and Newton County, Indiana. Sand prairies, marshes, and sand flatwoods were the predominant habitats of the poorly drained sites of this section before the land was drained for cultivation, while sand savannas were common on the drier sites.

All forest communities studied are located in the Iroquois County Conservation Area, Iroquois Co., Illinois, and the Willow Slough Fish and Wildlife Area, Newton Co., Indiana. The sand savanna communities are located on Plainfield fine sand (Wascher, Smith, and Odell, 1951). This fine sand is a light-colored soil derived from wind blown deposits. The sand sediment from which they were derived was deposited in Lake Watseka and Lake Wauponsee during the Kankakee Torrest which occurred during a major readvance of the Wisconsin Glacier about 13,000 years ago. Presently the sand savanna communities occur on the slopes and ridges of these dunes. The sand flatwood communities occur in depressions between the dunes on Iroquois fine sandy loam (Wascher, Smith, and Odell, 1951). This soil type usually consists of 1 meter or more of acid, peaty sand over thin layers of silt or clay (White, 1978). The present study was undertaken to determine the floristic composition of these forest communities.

Materials and Methods

The forested areas studied varied from one to two hectares in size. Each area was divided into quadrats 25 m on a side (0.15 acres), and the species, number, and size was recorded for each tree above 4 inches d.b.h. (10 cm). All living and dead-standing trees were identified and measured to the nearest 1/10 inch. The Importance Value (IV) was then calculated for each species in each of the forests sampled. As used here, the IV determination follows the procedure developed by McIntosh (1957) in which the IV is the sum of the relative density, relative dominance, and relative frequency. Also, the extent of coppice growth (multiple stemmed trees) in each area was determined, as well as the number of individuals and basal area (square feet) in broad diameter classes.

In each of the quadrats one 1/10,000 and one 1/100 hectare nested, circular plots were randomly located. The saplings (1-4 inches d.b.h.) were tallied on the larger plot, and the seedlings (less than 1 inch d.b.h.) on the smaller. Density and frequency of seedlings and saplings were calculated from these data. The nomenclature used in this paper follows Mohlenbrock (1975).

Results and Discussion

A total of eight forest areas were studied, four dry sand savanna communities, two dry-mesic sand savanna communities, and two sand flatwood communities. All tree species encountered in each area with their relative values, average diameters, and number and basal area per hectare in broad diameter classes, are included in Tables 1, 2, and 3. An additional listing of seedling and sapling density and frequency for

TABLE 1. *Number of trees and basal area per hectare by diameter classes, average diameters, relative values, and Importance Values of the woody vegetation in four dry sand savanna communities in the Kankakee Sand Area Section of nothern Indiana and Illinois.*

	Number of Trees and Basal Area per Hectare										Relative Values				
	4-6		7-12		13-18		19+		Totals		Rel.	Rel.	Rel.		Av. Diam.
	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	Freq.	Den.	Dom.	I.V.	in.
SITE 1. Willow Slough Fish and Wildlife Area, Newton Co., Indiana (Sec 5 T29N R9W).															
Quercus velutina	5	1.0	175	102.3	48	57.5	2	4.8	230	165.6	100.0	100.0	100.0	300.0	11.2
SITE 2. Iroquois County Conservation Area, Iroquois Co., Illinois (Sec 24 T29N R11W).															
Quercus velutina	25	4.3	61	33.7	50	67.7	12	27.6	148	133.3	94.1	98.3	99.1	291.5	12.0
Quercus alba	—	—	3	1.2	—	—	—	—	3	1.2	5.9	1.7	.9	8.5	9.1
Totals	25	4.3	64	34.9	50	67.7	12	27.6	151	134.5	100.0	100.0	100.0	300.0	
SITE 3. Willow Slough Fish and Wildlife Area, Newton Co., Indiana (Sec 18 T29N R9W).															
Quercus velutina	45	6.6	98	58.7	68	84.1	16	38.2	227	187.6	80.0	97.8	97.0	274.8	11.5
Quercus alba	1	.1	2	.8	—	—	2	5.0	5	5.9	20.0	2.2	3.0	25.2	12.8
Totals	46	6.7	100	59.5	68	84.1	18	43.2	232	193.5	100.0	100.0	100.0	300.0	
SITE 4. Iroquois County Conservation Area, Iroquois Co., Illinois (Sec 24 T29N R11W).															
Quercus velutina	17	2.3	35	19.6	45	63.7	15	36.7	112	122.3	66.7	77.8	82.7	227.2	13.1
Quercus alba	10	1.7	10	6.3	10	13.0	2	4.6	32	25.6	33.3	22.2	17.3	72.8	11.1
Totals	27	4.0	45	25.9	55	76.7	17	41.3	144	147.9	100.0	100.0	100.0	300.0	

TABLE 2. *Number of trees and basal area per hectare by diameter classes, average diameters, relative values, and Important Values of the woody vegetation in two dry-mesic sand savanna communities in the Kankakee Sand Area Section of northern Indiana and Illinois.*

	Number of Trees and Basal Area per Hectare										Relative Values				
	4-6		7-12		13-18		19+		Totals		Rel.	Rel.	Rel.		Av. Diam.
	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	Freq.	Den.	Dom.	I.V.	in.
SITE 5. Iroquois County Conservation Area, Iroquois Co., Illinois (Sec. 24 T29N R11W).															
Quercus velutina	29	4.6	71	43.0	20	26.8	12	30.1	132	104.5	53.3	67.3	72.2	192.8	11.1
Quercus alba	24	3.4	21	11.1	16	20.6	2	4.8	63	39.9	43.3	32.2	27.6	103.1	9.7
Prunus serotina	1	.2	—	—	—	—	—	—	1	.2	3.4	.5	.2	4.1	5.9
Totals	54	8.2	92	54.1	36	47.4	14	34.9	196	144.6	100.0	100.0	100.0	300.0	
Site 6. Willow Slough Fish and Wildlife Area, Newton Co., Indiana (Sec 5 T29N R9W).															
Quercus alba	54	9.1	63	34.9	32	39.5	3	8.3	152	91.8	48.5	51.7	44.6	144.8	9.6
Quercus velutina	9	1.6	79	45.3	42	54.0	3	7.2	133	108.1	45.5	45.2	52.6	143.3	11.2
Quercus coccinea	—	—	6	2.6	3	3.1	—	—	9	5.7	6.0	3.1	2.8	11.9	10.5
Totals	63	10.7	148	82.8	77	96.6	6	15.5	294	205.6	100.0	100.0	100.0	300.0	

TABLE 3. *Number of trees and basal area per hectare by diameter classes, average diameters, relative values, and Important Values of the woody vegetation in two sand flatwood communities in the Kankakee Sand Area Section of northern Indiana and Illinois.*

	Number of Trees and Basal Area per Hectare										Relative Values				
	4-6		7-12		13-18		19+		Totals		Rel.	Rel.	Rel.		Av. Diam.
	No.	B.A.	No.	B.A	No.	B.A.	No.	B.A.	No.	B.A.	Freq.	Den.	Dom.	I.V.	in.
SITE 7. Willow Slough Fish and Wildlife Area, Newton Co., Indiana (Sec 18 T29N R9W).															
Quercus palustris	25	4.0	114	65.6	57	75.7	8	19.9	204	165.2	45.7	65.4	69.9	181.0	11.5
Quercus alba	23	3.8	26	12.7	10	14.2	12	35.2	71	65.9	28.6	22.8	27.9	79.3	11.3
Nyssa sylvatica	35	4.3	2	.8	—	—	—	—	37	5.1	25.7	11.8	2.2	39.7	4.9
Totals	83	12.1	142	79.1	67	89.9	20	55.1	312	236.2	100.0	100.0	100.0	300.0	
SITE 8. Iroquois County Conservation Area, Iroquois Co., Illinois (Sec 24 T29N R11W).															
Quercus palustris	159	27.1	275	126.5	19	24.0	3	7.7	456	185.3	60.0	91.8	92.8	244.6	8.2
Quercus alba	22	3.8	14	5.2	3	5.0	—	—	39	14.0	30.0	7.6	7.0	44.6	7.5
Nyssa sylvatica	3	.3	—	—	—	—	—	—	3	.3	10.0	.6	.2	10.8	4.3
Totals	184	31.2	289	131.7	22	29.0	3	7.7	498	199.6	100.0	100.0	100.0	300.0	

TABLE 4. *Frequency and density of seedlings and saplings in six sand savanna communities and two sand flatwood communities in the Kankakee Sand Area Section of northern Indiana and Illinois.*

	Seedlings		Saplings	
	Freq.%	#Ind.	Freq.%	#Ind.
SITE 1: Dry Sand Savanna				
Quercus velutina	25	2500	19	50
SITE 2: Dry Sand Savanna				
Quercus velutina	53	8125	56	150
Quercus alba	—	—	13	16
Prunus serotina	—	—	13	25
Totals		8125		191
SITE 3: Dry Sand Savanna				
Quercus velutina	81	25625	69	206
Quercus alba	—	—	13	50
Prunus serotina	6	625	50	81
Sassafras albidum	15	5000	13	13
Totals		31250		350
SITE 4: Dry Sand Savanna				
Quercus velutina	63	15625	38	88
Quercus alba	6	125	44	63
Prunus serotina	—	—	13	25
Sassafras albidum	6	125	—	—
Totals		15875		176
SITE 5: Dry-mesic Sand Savanna				
Quercus velutina	38	4375	50	175
Quercus alba	—	—	44	113
Prunus serotina	6	625	13	19
Totals		5000		307
SITE 6: Dry-mesic Sand Savanna				
Quercus alba	50	7500	63	181
Quercus velutina	13	2500	25	106
Sassafras albidum	6	625	25	106
Prunus serotina	—	—	44	106
Nyssa sylvatica	—	—	6	13
Totals		10625		512
SITE 7: Sand Flatwood				
Quercus palustris	25	8750	13	38
Quercus alba	—	—	19	38
Nyssa sylvatica	—	—	38	256
Totals		8750		332
SITE 8: Sand Flatwood				
Quercus palustris	13	4375	19	25
Quercus alba	—	—	6	6
Totals		4375		31

all woody species encountered in each area is shown in Table 4, while the number of dead-standing trees, and the extent of coppice growth in each area is shown in Table 5.

TABLE 5. *Number and basal area of dead-standing trees, and the extent of coppice growth in six sand savanna communities and two sand flatwood communities in the Kankakee Sand Area Section of Indiana and Illinois.*

SITE	Dead-standing trees per hectare		Coppic growth per hectare	
	No.	B.A.	% stems	% B.A.
1	45	12.5	14	13
2	8	5.4	42	28
3	21	17.6	20	20
4	14	14.3	18	12
5	4	3.5	43	34
6	19	6.0	32	26
7	51	25.9	20	20
8	113	15.9	41	33

In the dry sand savanna communities studied (Sites 1 thru 4), which are common on the ridges and upper slopes of dunes, *Quercus velutina* Lam. is the dominant species, accounting for nearly all of the Importance Value. The only other tree species encountered is *Q. alba* L., which varies in Importance Value from 8.5 to 72.8 (Table 1). At sites 2 and 4, located at the Iroquois County Conservation Area, the number of stems per hectare varies from 144 to 151; while on sites 1 and 3, located at the Willow Slough Fish and Wildlife Area, the number varies from 230 to 232. This difference is due to the excessive number of individuals in the 7-12 inch diameter class, and indicates that the forests at the Willow Slough Fish and Wildlife Area have not been burned as often. At the Iroquois County Conservation Area most sites are burned every three years (site manager-personal communication), while at the Willow Slough Fish and Wildlife Area fire has just recently been used in forest management (John Bacone-personal communication). Except for site 1, which was burned during the spring, the number of seedlings found is relatively high (Table 4). Few of these survive, however, as indicated by the low density of saplings (50 to 350 per hectare).

The dry-mesic sand savanna communities studied (Sites 5 and 6) occur on the lower slopes of the dunes. In this community type both *Quercus velutina* and *Q. alba* are important stand components with each species accounting for about half of the Importance Value. At these sites the number of individuals per hectare varies from 196 to 294, while the basal area per hectare ranges from 144 to 205 square feet (Table 2). Seedling density is also relatively high in these communities (Table 4), although saplings are not very extensive (307 to 512 per hectare). The larger number of seedlings, saplings, and trees per hectare on the dry-mesic sand savanna at the Willow Slough Fish and Wildlife Area (Site 6) is probably due to fire suppression in the past.

The sand flatwood communities studied (Sites 7 and 8) occur in depressions between dunes. Here *Quercus palustris* Muenchh. is dominant, accounting for 60 to 80% of the Importance Value. *Quercus alba*, with an IV of 44 to 79 is also common, particularly at slightly higher elevations, while *Nyssa sylvatica* Marsh. is occasionally encountered (Table 3). These forests have the highest tree densities encountered during the present study (312 to 498 stems per hectare). Water availability and fire suppression at these sites probably account for these higher densities. The large number of individuals (nearly 500) at site 8, and the low average diameter indicate that this site was cut-over in the past, or that due to fire suppression has recently undergone succession from shrub prairie or wet-mesic sand prairie (White, 1978).

Dead-standing trees are relatively common in the sand flatwood communities (Sites

7 and 8), and one of the dry sand savanna communities (Site 1). On these sites the number of dead-standing trees varies from 45 to 113 stems per hectare with most of the individuals in the 4-6 and 7-12 inch diameter classes. In contrast, dead-standing individuals are not an important stand component in the remaining sand savanna communities (Table 5). In these communities between 4 and 21 dead-standing trees are found per hectare.

Coppice stems are relatively common in the forest areas studied (Table 5). Though these multiple stemmed trees could be the result of past cutting, it is more probable that they are due to fire which kills the above ground parts of saplings and small trees, with the resulting sprouts developing into forest trees.

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Effects of Harvest Management on Dry Matter and Crude Protein Yields of *Medicago Sativa* L.

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Introduction

Medicago sativa L. commonly called alfalfa, is probably the world's most important forage (hay) crop with the largest production in the United States, Argentina and Canada. Without alfalfa, it is doubtful if the dairy industry in these countries would have been as successful as it has been.

Alfalfa may be productive up to 15 or more years if judiciously managed, but indiscrete management may wipe out an otherwise promising crop. This experiment was conducted to determine the effects of cutting frequency on alfalfa DM and CP yields, and longevity of stand.

Materials and Methods

The experiment was conducted on a Chalmers silty clay loan (Typic Haploquall, fine-silty, mixed, mesic) soil located on the Purdue University Agronomy farm. The alfalfa cultivar used was Apollo which was seeded at the rate of 11.21 kg/ha on April 16, 1976, using a Brillion seeder. The experimental design was a randomized complete block with six replications, each with eight treatments. Individual plots measured 6.10m x 1.83m. Fertilizer application was made annually in two split doses at the rates of 112 kg/ha P_2O_5 and 336 kg/ha K_2O. There were two harvest dates: an early cut initially harvested on May 11, and a late cut, initially harvested on June 1. The interval between cuts were 4, 5, 6 or 7 weeks giving annual harvests of 6, 5, 4, and 4 respectively. All plots were harvested with a Carter Harvester. Samples were dried using hot air ovens at 70°C for 5 days before being ground for laboratory analysis. Total N concentration was determined by the Kjeldahl procedure outlined in AOAC (1).

Results and Discussion

Dry matter and crude protein yields for the three years are presented in Table 1. Dry matter yields showed significant differences (P 0.01) between early and late hay harvests in all three years of the experiment. There were also significant differences among intervals between cuts. Testing for interaction between cutting dates and intervals between cuts indicated a significantly higher yield at the 6-week cutting interval in 1978 and 1979. These results indicate that the dry matter yield of alfalfa depends on maturity as well as on the interval between harvests. Harvests based on fixed calendar dates seem unrealistic as they do not consider the physiological stage of development of the plant. Moreover, they totally disregard the fact that plant maturity on a certain date may vary among years, locations and cultivars, Smith (8). The high hay yields obtained in this experiment from the late cuts resulted from the 3-week gap between the early and late cuts, enabling the late cuts to accumulate higher DM than the early cuts. These results are consistent with the findings of Bishop and Gramshaw (2), Pacuta (4), Ral *et al.* (5), and Schmid *et al.* (7). Apparently, the early 4-week harvests sufficiently weakened the alfalfa plants resulting in a markedly reduced yield in 1980.

The CP yields showed significant differences particularly in 1980; in 1978 and 1979, only the date by frequency interaction showed a significant difference. The trends

TABLE 1. *Comparative CP and DM Yields (kg/ha).*

CP/DM: Cut	Weeks between cuts 4	5	6	7
		1978		
CP: Early Cut	2162	2247	1989	2171
CP: Late Cut	2050	2071	2551	2244
DM: Early Cut	11062	12114	10470	11549
DM: Late Cut	10838	11184	13027	12971
		1979		
CP: Early Cut	2431	2475	2153	2352
CP: Late Cut	2392	2168	2354	2370
DM: Early Cut	12540	12995	11881	13193
DM: Late Cut	13437	12141	14154	14367
		1980*		
CP: Early Cut	546	798	832	912
CP: Late Cut	746	837	838	887
DM: Early Cut	3142	4525	4725	5226
DM: Late Cut	4396	4928	4925	5102

* 1 harvest only—all treatments cut same day in 1980.

in 1978 and 1979 were similar and indicated that at 4 and 5 weeks between harvests, the early cut had a higher CP yield, but at the 6 and 7 weeks between cuts, the trend was reversed. The CP of the first cut was lower than that of the second cut at the 5 week harvests and agrees with the finding of Schmid *et al.* (7).

The probable reason for a reversal in trend after the 5-week intervals between cuts was that generally CP accumulation did not vary much, whereas DM yield varied greatly among treatments. The early cuts generally had a higher CP concentration and lower DM yields while the late cuts had somewhat lower CP concentrations but high DM yields. Since the CP yield is a product of the DM yield and CP concentration, the expected trends occurred.

The data of this experiment indicate that the livestock producer can produce the quality of alfalfa forage desired by altering the cutting interval. A short cutting interval results in higher CP concentration and reduced DM yield while a longer cutting interval results in lower CP concentration and higher DM yields.

Thus, farmers with beef cow herds would harvest their hay at long intervals whereas dairy farmers whose animals require high quality alfalfa hay and silage, in terms of CP, would harvest at shorter intervals. It must be stressed, however, that too short a cutting interval is detrimental to alfalfa persistence. Farmers faced with this problem may want to apply the findings of Ossom *et al.* (3) which suggested that number of stems rather than number of crowns per unit area may be a better indicator of stand vigor and persistence.

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Post Wind Damage Survey of Herbaceous Level in Bendix Woods Nature Preserve, St. Joseph County, Indiana

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The Bendix Woods Nature Preserve, an old growth beech-sugar maple-black maple forest, is located in western St. Joseph County, ca. 19 km west of South Bend, Indiana. This report is part of a larger study (5) initiated in the spring of 1981 to assess the damage caused when consecutive windstorms on July 5 and 9, 1980 extensively damaged about 25 percent of the preserve area.

Two previous papers (2,5) describe the historical and physical features of the preserve area as well as the flora and community parameters of the canopy/small tree levels of the forest community.

One additional objective of our study is to provide base line data for continuing studies of the forest recovery process. This report presents the data for 100 random, circular, permanent herbaceous level plots established in May, 1981 and resurveyed in the springs of 1982 and 1983.

Methods

The coordinates for 100 herbaceous quadrat sites (Table 1) were selected using a random numbers table. Two sets of three sequential numbers were obtained from the table. The first set determined the distance in meters west of the southeast corner post of the preserve. The second set determined the distance north. If the grid point was outside of or within 20 m of the edge of the preserve, a new set of numbers was drawn. Since the western boundary of the preserve was not clearly defined by a fence or trail, the western limit was set at 400 m west which corresponds to the western edge of the old growth forest. The numbers were plotted on the preserve base map in the sequence they were drawn.

Plots were located in the field by pacing from known reference points, i.e. the marked corners of the 50 m square quadrats being established for canopy inventory (5). Plots initially located in a trail were moved 2 m in the compass direction of the trail's nearest edge. All plots were at least 1.5 m from the edge of a trail. Each plot was marked by a 1.9 cm by 61 cm galvanized iron pipe driven in the center of the plot.

The plots were established and inventoried during the period May 18 through 28, 1981. In addition, a determination of the disturbance status of the plot was made using three categories, 1) undisturbed, 2) disturbed in July, 1980 windstorms, and 3) disturbed by a neary trail or recent windthrow that occurred before 1980 (See Status Column in Table 1). Plots were inventoried by using an L shaped rod placed in a cork in the top of the pipe. The length of the rod (0.6 m) defined the radius of the plot. All herbaceous species and woody species less than one meter tall within the radius were recorded. The number of individuals was recorded for tree species and two herbaceous species (*Phytolacca americana* and *Impatiens pallida*). The plots were

TABLE 1. *Location and disturbance category of 100, 1.2 m diameter plots in Bendix Woods Nature Preserve, St. Joseph County, Indiana. (1)*

Plot		Distance		Plot		Distance		Plot		Distance	
#	S	W	N	#	S	W	N	#	S	W	N
1	U	138	106	2	D1	267	172	3	D1	358	96
4	U	364	159	5	D1	194	133	6	U	355	231
7	D1	287	236	8	D2	353	259	9	U	278	146
10	D1	275	223	11	U	319	80	12	D1	354	72
13	D1	359	135	14	D1	227	177	15	U	321	37
16	D1	353	93	17	U	273	30	18	D1	280	312
19	U	135	140	20	D1	360	146	21	U	245	69
22	D1	273	291	23	D1	261	232	24	D2	281	181
25	U	322	158	26	U	246	76	27	U	396	179
28	U	247	135	29	D1	369	80	30	D1	265	304
31	D1	282	214	32	D1	277	246	33	U	151	99
34	D1	343	111	35	U	133	123	36	D1	163	46
37	U	349	187	38	D1	336	240	39	U	107	108
40	U	369	206	41	D1	352	96	42	D1	253	154
43	D2	164	80	44	D1	345	71	45	D1	279	250
46	D1	173	133	47	D1	251	159	48	U	87	91
49	U	114	62	50	U	47	21	51	U	312	269
52	U	253	30	53	U	366	105	54	U	47	46
55	U	246	27	56	U	41	76	57	D1	305	197
58	D1	302	176	59	U	254	110	60	U	371	226
61	U	117	61	62	D1	280	233	63	D1	310	210
64	D2	322	131	65	D2	212	90	66	U	67	86
67	U	128	60	68	U	384	204	69	D1	335	235
70	U	227	84	71	D2	302	139	72	D1	266	238
73	D1	265	135	74	U	323	235	75	U	113	109
76	D2	259	127	77	U	356	171	78	D1	346	75
79	U	305	265	80	U	352	159	81	D1	321	224
82	U	161	149	83	D1	356	145	84	D1	231	173
85	D1	269	268	86	U	339	96	87	U	392	127
88	U	168	120	89	U	298	33	90	U	334	145
91	U	294	242	92	U	233	103	93	D1	221	109
94	D1	264	292	95	D2	147	65	96	U	329	66
97	U	391	240	98	D2	108	105	99	U	334	211
100	D2	123	40								

1. Distance is measured in meters from the southeast corner post of chainlink fence. The W and N are the distances west and north of corner post. Plots are marked with 1.9 X 61 cm galvanized pipe driven in center of plot. The S under Plot refers to disturbance category: U-no recent disturbance, D1-plot impacted by 1980 windthrows, and D2-plot near trail or other evidence of disturbance.

inventoried again in the fall of 1981, twice in the spring of 1982 (April 22-30 and May 18-24) and twice in the spring of 1983 (May 4-10 and May 27-June 2).

Results and Discussion

Eighty two taxa were recorded within the 100 random plots. Since species distinctions were not made for four genera of tree species, *Acer*, *Ulmus*, *Fraxinus* and *Prunus*, the eighty two taxa represent 73 percent of the species reported for the preserve (2). A majority of the species not included in the random samples were either relatively rare within the preserve or had a limited distribution. In general, the distribution of plots resulted in the sample containing most of the topographic, soil and community variation within the preserve as well as nearly equal numbers of plots in disturbed and undisturbed areas.

Table 2 presents the frequency data for all species present in five percent or more of the plots. (A complete list of species and their frequencies may be obtained from the senior author or Indiana Division of Nature Preserves.) Species are listed in descending order of the 1982 frequency values calculated from total (100 plots) presence data.

TABLE 2. *Frequency values for taxa in 100 random, circular, permanent plots in Bendix Woods Nature Preserve in western St. Joseph County, Indiana. Data collected in the springs of 1981, 1982 and 1983. Species with values less than 5 percent are not included.*

	Frequency (%)[1]								
	All			U			D1		
Species	81	82	83	81	82	83	81	82	83
Galium aparine	95	98	85	94	99	88	97	95	80
Dicentra canadensis	82	78	76	80	74	78	82	82	75
Claytonia virginica	28	78	69	40	92	80	12	62	55
Dicentra cucullaria	63	71	88	64	66	82	57	70	92
Acer saccharum	55	70	57	52	72	50	55	67	62
Impatiens pallida	54	66	70	30	36	44	75	97	97
Erythronium americanum	11	49	43	8	50	44	15	47	40
Isopyrum biternatum	42	44	43	40	44	44	45	47	45
Parthenocissus quinquefolia	38	42	47	38	46	48	35	40	47
Dentaria laciniata	10	35	36	14	42	50	0	25	15
Smilacina racemosa	29	34	34	34	40	38	20	25	27
Erigenia bulbosa	7	29	25	10	36	32	5	17	12
Viola pensylvanica	28	28	30	34	34	36	17	17	20
Ulmus sp.	19	27	35	16	26	28	25	30	45
Viola canadensis	21	22	23	24	24	24	17	20	22
Arisaema atrorubens	18	22	26	20	18	22	15	25	27
Osmorhiza claytoni	19	21	30	18	18	22	15	15	37
Lindera benzoin	19	19	19	18	20	18	15	15	15
Floerkea proserpinacoides	21	19	25	26	24	32	10	10	12
Carya cordiformis	21	19	17	22	18	16	20	17	15
Asarum canadense	11	18	20	18	26	26	5	12	17
Phlox divaricata	18	17	23	24	20	30	15	17	20
Asimina triloba	14	16	21	12	12	18	7	12	17
Euonymus obovatus	9	14	10	10	16	14	10	15	7
Polygonatum pubescens	10	13	13	6	10	12	12	12	10
Sanicula trifoliata	10	12	14	16	18	16	2	5	10
Prunus sp.	4	11	9	2	8	10	7	10	5
Hydrophyllum appendiculatum	10	11	10	4	6	8	20	20	15
Trillium grandiflorum	8	10	8	10	10	8	7	12	10
T. flexipes	3	7	5	6	12	8	0	2	2
Phytolacca americana	11	7	10	0	0	0	25	17	25
Caulophyllum thalictroides	4	7	5	4	6	4	5	7	7
Osmorhiza longistylis	7	6	9	8	6	4	7	7	17
Podophyllum peltatum	5	5	5	6	6	6	5	5	5
Geranium robertianum	7	5	6	4	2	2	12	10	12
Circaea quadrisulcata	6	5	9	10	6	10	2	5	7
Stylophorum diphyllum	5	4	4	0	0	0	10	7	7
Phryma leptostachya	4	4	8	6	4	8	0	5	7
Hydrophyllum canadense	4	4	5	8	8	8	0	0	2
Fagus grandifolia	10	4	9	14	4	12	7	2	7
Carex albursina	3	4	5	0	0	0	7	10	12
Tovaria virginiana	2	3	5	4	2	6	0	5	5
Geum canadense	2	2	5	2	2	2	2	2	10

1. The abbreviations above the columns represent: U-undisturbed plots, D1-plots in 1980 windthrow area, All-all the data from the 100 plots and the numbers below a subheading are the last two digits of the year of inventory.

Values for 1982 and 1983 are based on the combined results of both early and late spring surveys, whereas 1981 values are based on a single mid- to late spring inventory supplemented by a partial late fall survey. Since the 1981 inventory period extended past the normal senescence dates for *Claytonia virginiana, Erigenia bulbosa, Erythronium americanum* and *Dentaria laciniata*, their 1981 values are too low. The visible presence of corms of *Dicentra* sp. during the fall 1981 inventory enabled us to correct the spring values and calculate accurate frequency values for these two early spring species.

In addition to total frequency values, the table contains the frequency values for undisturbed plots (50 plots) and plots within the area damaged by the July, 1980 windstorms (Disturbed, 40 plots). Plots in the latter category range from being located under windthrown tops to no physical disturbance of plot but canopy above the plot is gone. None of the random plots are located on a fresh windthrow mound or within a pit but a few plots are on older windthrow mounds within the new windthrow area. The remaining ten plots are in areas of past disturbance or near trails. Since one objective is to assess the impact of the July, 1980 storms, these plots are not used in comparison of disturbed and undisturbed areas.

The ranking of the top twenty species in Table 2 varies from year to year, particularly between disturbed and undisturbed plots. *Galium aparine* has the highest frequency value for both total plots and undisturbed plots for all three years but ranks behind *Impatiens pallida* in disturbed plots in 1982 and 1983. *Impatiens* ranks tenth in the undisturbed plots. Most spring ephemerals have high frequencies and dominate the top ten species in Table 2 although *Dentaria laciniata* has a lower rank in disturbed plots. Two other ephemerals, *Erigenia bulbosa* and *Floerkea proserpinacoides* have considerably lower frequencies in disturbed versus undisturbed plots. *Phytolacca americana*, a summer species, is not present in undisturbed plots but ranks in the top 20 species in disturbed plots.

If cover data had been collected, *Galium aparine* would have a lower ranking in all categories and years since it does not form the extensive, dense early spring colonies like *Dicentra* sp., *Isopyrum* and *Impatiens pallida*. The decision not to collect cover data may have resulted in the loss of important information. Rogers (6), in a study of the effects of an extremely warm and dry early spring on herbaceous flora, found no significant differences in number of species or frequency values but did find significant differences in cover values. The limited time we had available to establish and inventory the plots in 1981 was the major reason we decided not to collect cover data. We have not been able to inventory the plots in less than two days and usually the inventory periods were separated by one to several days. We have observed over the past three springs, fairly rapid changes in cover within periods as short as three days.

Levenson (3) included Bendix Woods as one of 21 stands he sampled in a study of the herbaceous level of the beech-maple forest region. Since his data were collected in mid-summer, none of the spring ephemerals was included. His table for Bendix Woods lists 45 species, including three species not found in our plots. One of these species, *Mitella diphylla*, was not located by us. Four species, *Impatiens pallida, Parthenocissus quinquefolia, Acer saccharum* and *Viola pensylvanica*, had frequency values of 50 or greater and the first two accounted for 63 percent of the total stems. Beyond his top five species, there were considerable differences between species rankings in the two sets of data.

The major change in the herbaceous layer in the windthrow areas has been the explosive growth of the *Impatiens pallida* population. We visited the windthrow area in September, 1980, two months after the storms, and the abundant growth of *Impatiens* was evident in much of the area. One other herbaceous species, *Phytolacca*

americana, appeared to be increasing in the damaged areas. This was the main reason we decided to collect density data for these two species when we established and inventoried the plots in May, 1981. For all sampling periods except September, 1983, the density of *Impatiens* was significantly greater in the disturbed areas of the preserve although the individual plot values were more variable than in undisturbed plots. Some of the disturbed plots had so much debris on them, only a few species or individuals were present.

Throughout the windthrow area, *Impatiens pallida* seedlings form dense stands by late April although germination is not complete until May. The large cotyledons effectively cover most of the available space and, as the stems elongate and leaves expand, the *Impatiens* canopy forms dense shade. The plants mature rapidly and begin flowering by mid June and continue until frost. Plants usually reach maximum size by late July with some stems more than 2 meters tall and the population forms a dense thicket over large areas. This is the major reason we did not attempt to inventory the plots in mid-summer.

The maximum stem count for *Impatiens* was 345 stems in a plot. Our field observations indicate that mortality is high from germination to maturity. At first, germinating individuals replace many of the dying individuals until peak density is reached in early May, then there is a decline in numbers to maturity. The April density values in Table 3 are prior to peak density and the May, 1982 values are after peak density. The early May 1983 values probably record peak density and the effects of mortality are shown by the decline in late May. The summer of 1983 was hot and dry and the stand never reached the robustness of 1981 or 1982. We did not do a summer inventory but the early fall inventory, completed before a frost, indicates that few individuals survived.

The dramatic increase in size of the *Impatiens* population must be due to a soil seed bank or some dispersal mechanism other than the explosive capsule. It is not one of the ant dispersed species as are many of the other forest floor herbs (1). Since *Impatiens* does occur fairly frequently and in low but constant numbers in the undisturbed plots, there is probably a fairly good seed pool in most areas of the forest. Levenson (3) reported *Impatiens* densities more than double our highest average values for undisturbed plots. Since his plots appear to have been located in the windthrow and adjacent areas, the initial population density of *Impatiens* may have been higher

TABLE 3. *Density values for* Impatiens pallida *for Bendix Woods Nature Preserve based on date from 100, 1.2 m diameter, permanent plots surveyed in the springs of 1981, 1982 and 1983.*

Sampling dates:	Density (#/m^2) Total Avg. 95% conf.	Undisturbed Avg. 95% conf.	Disturbed Avg. 95% conf.
1981			
May 18-24	13.0 6.7-19.6	1.4 0.4-2.3	29.9 14.8-45.0
1982			
Apr 22-30	18.5 11.1-25.9	1.9 0.7-3.2	39.2 23.1-55.2
May 18-24	24.0 15.8-32.2	2.9 0.7-5.1	51.6 34.8-68.3
1983			
May 4-10	27.2 18.0-36.4	3.3 1.1-5.5	59.1 40.4-77.8
May 27-Jun 2	21.7 15.2-28.1	3.1 1.1-5.0	46.1 33.9-58.3
Sep 21-26	0.4 0.1-0.8	.02 0.0-.05	1.1 0.3-1.8

than our data would indicate. No data on seed production was obtained in either disturbed or undisturbed areas.

One of our objectives is to obtain base line data to study forest regeneration in the preserve. Therefore, we tallied the number of tree seedlings in each plot. The density values for the five species with highest values are presented in Table 4. No clear seedling response to the windthrow disturbance by any of the tree species is indicated by the data or field observations. *Acer* seedling frequency and density values are the highest for all tree seedlings and are distantly followed by *Ulmus* and *Carya cordiformis*. *Acer* ranks in the top ten frequencies in the herbaceous layer and *Ulmus* is in the top 20.

As stated earlier, the fall 1983 inventory was made because St. Joseph County experienced one of the hottest and driest summers on record. Based on the data in Table 4, the impact on tree seedlings was slight except for *Prunus serotina*. The *Prunus* data may be wrong since the seedlings may have lost their leaves earlier than normal and were not recorded.

Chi Square, Cole's and Poole's point correlation association coefficients (4) were calculated for 1982 and 1983 data for all species pairs that occurred in ten or more plots i.e. species with total frequency values of 10 or larger in Table 2. Fifteen species had chi square values that were significant at the 95 percent level for both 1982 and 1983. Three taxa, *Acer, Dentaria* and *Floerkea*, had three or more associations. *Viola canadensis* was negatively associated with *Floerkea* and positively associated with *Ulmus*

TABLE 4. *Density values for tree seedlings less than one meter tall in 100 random, 1.2 m diameter plots in Bendix Woods Nature Preserve, St. Joseph County, Indiana.*

Species		Density Values (#/m^2) Spring 1981		1982		1983		Fall 1983	
(1)	(2)	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Acer saccharum	A	1.68	0.27	3.96	0.56	1.92	0.32	1.29	0.21
	U	2.01	0.48	5.04	0.87	2.05	0.53	1.22	0.31
	D	1.06	0.21	1.94	0.41	1.81	0.45	1.39	0.33
Asimina triloba	A	0.12	0.03	0.26	0.10	0.15	0.04	0.19	0.05
	U	0.11	0.04	0.30	0.18	0.14	0.06	0.18	0.07
	D	0.07	0.04	0.11	0.05	0.07	0.04	0.13	0.06
Carya cordiformis	A	0.23	0.05	0.22	0.05	0.20	0.05	0.18	0.05
	U	0.27	0.08	0.25	0.08	0.21	0.07	0.21	0.08
	D	0.20	0.07	0.18	0.06	0.13	0.05	0.13	0.06
Prunus serotina	A	0.04	0.02	0.15	0.06	0.13	0.05	0.0	0.0
	U	0.02	0.02	0.14	0.09	0.14	0.07	0.0	0.0
	D	0.08	0.05	0.13	0.07	0.07	0.05	0.0	0.0
Ulmus rubra	A	0.28	0.07	0.37	0.07	0.43	0.08	0.28	0.06
	U	0.21	0.10	0.39	0.11	0.27	0.07	0.21	0.08
	D	0.38	0.13	0.35	0.09	0.68	0.17	0.40	0.11

1. *Acer saccharum* includes *A. nigrum*. *Ulmus rubra* may include a few *U. americana*. Other species present in small numbers are: *Celtis occidentalis, Fagus grandifolia, Fraxinus* sp., *Liriodendron tulipifera, Quercus rubra* and *Tilia americana*.

2. The letters in column represent: A-all plots, U-undistrubed plots and D-plots in July 1980 windthrow area. The row to the right of number: Avg.-average number per square meter and SE-standard error of mean.

rubra. The remaining four taxa have simple positive associations, *Polygonum pubescens* with *Arisaema atrorubens* and *Asarum canadense* with *Sanicula trifoliata*.

Acer seedlings are positively associated, in both years, with *Claytonia virginiana, Erythronium americanum, Parthenocissus quinquefolia* and *Ulmus* sp.. *Ulmus* is a common canopy associate with beech and maple in Bendix Woods and its association with maple at the forest floor should be expected. The other species are common members of the mesic forests in northern Indiana, particularly beech-maple forests.

Floerkea proserpinacoides is positively associated with *Smilacina racemosa, Erigenia bulbosa* and *Dentaria laciniata*. *Dentaria* is positively associated with *Erigenia* also. Both *Dentaria* and *Floerkea* are negatively associated with *Isopyrum biternatum*. *Isopyrum* forms dense robust colonies and few other species are found in the same quadrats. Also, our observations of spring flowering indicate that the flowering periods of the above positively associated species only slightly overlap whereas *Isopyrum* overlaps all of them.

Summary

One hundred, 1.2 m diameter permanent plots were established and inventoried in Bendix Woods Nature Preserve in May 1981. Only species presence was recorded for a majority of the herbaceous and shrub species. Number of individuals was recorded for all tree seedlings less than one meter tall and for two herbaceous species, *Impatiens pallida* and *Phytolacca americana*.

Species with frequency values greater than 50 percent were: *Galium aparine, Dicentra canadensis, D. cucullaria, Claytonia virginica, Impatiens pallida* and *Acer* sp. *Impatiens pallida* had the greatest population growth, size and numbers, response to the opening of the canopy by the July 1980 wind storms. *Impatiens* population densities averaged 59 individuals per m^2 in the disturbed area in early May, 1983. Maple had the greatest density among the tree seedlings with elm a distant second.

The chi square test was used to determine siginificant species associations. *Isopyrum biternatum* was the only species that was negatively associated with four other species at the 5 percent level. Two of the species involved, *Dentaria laciniata* and *Floerkea proserpinacoides*, were positively associated with each other and several other species.

Acknowledgments

We are grateful for grants-in-aid provided by Indiana Academy of Science and Indiana University at South Bend. Computer time and servies of the IUSB Computer Center are gratefully acknowledged. We thank the Indiana Division of Nature Preserves and the St. Joseph County Parks and Recreation Board for permission to use Bendix Woods Nature Preserve and park facilities.

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ENGINEERING

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ABSTRACTS

Prediction of PWR Reactivity Coefficients Using LEOPARD. RAYDO BUGAYONG, St. Joseph's College, Rensselaer, Indiana 47978.——In the process of licensing nuclear power reactors, the reactor vendors and utilities are required to predict as well as measure reactivity coefficients and to report these in the Preliminary Safety Analysis Report. In doing this, the vendors expend considerable time and effort using sophisticated computer codes. The main objective of this paper is to determine the relative accuracy obtainable in predicting certain reactivity coefficients by using a relatively simple and (more importantly) readily available computer code named LEOPARD.

The particular reactivity coefficients of interest are the moderator temperature coefficient, Doppler coefficient and the soluble boron reactivity worth. It has been observed that the reactivity coefficient predictions are significantly dependent upon the fuel temperature calculation models used. In particular, the effective resonance temperature model and gap conductance model, of which there are several, can have a significant effect on the predicted reactivity coefficients. Inspite of the above limitations however, LEOPARD calculations, especially the boron reactivity worth and moderator temperature coefficients are shown to agree reasonably well when compared to the WUP PSAR. This is also true with the prection of the Doppler only power defect and the total power defect. Hence, these results show that by arriving at an appropriate fuel temperature calculation model, the LEOPARD code can predict the above mentioned reactivity coefficients reasonably well.

On the Need for Engineers Trained in Biotechnology. DAVID D. CHESAK, St. Joseph's College, Rensselaer, Indiana 47978.——Recent advances in the biological sciences promise to revolutionize many industries as well as promote entirely new ones. For example, the latest development, popularly referred to as genetic engineering, has been applied to the production of human insulin using a bacterial vector. It is anticipated that food processing, energy supply, pharmaceutical manufacturing, synthetic material production, waste recycling and fertilizer manufacture are some of the areas that will be impacted. As these changes come about, there will be a need for people who have training in microbiology, biochemistry, fermentation technology and chemical engineering. At present, very few universities offer a bachelor of science degree program that incorporates all of these disciplines. It is felt that, to meet the future needs of our society, we should consider now curricula of this type.

The Viscosity Determination of a Non-Newtonian Fluid. ROBERT H. L. HOWE, West Lafayette, Indiana 47906 and DAVID J. HOWE, Columbia, Missouri 65201.——The procedure for determining the viscosity of a heavy bio-oxidation substrate is presented. The mathematical relationship of the viscosity and the rotational speed is derived. Some experimental data are illustrated.

ENTOMOLOGY

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ABSTRACTS

Papaipema nebris, **the Common Stalk Borer, a New Pest on the Bitter Gourd** (*Momordica* sp.) Grown in Indiana. Joseph T. Chowattukunnel, Department of Biology, Indiana University at South Bend, South Bend, Indiana 46634 and R. Bruce Cummings, Indiana Department of Natural Resources, Indianapolis, Indiana. 46204.——The senior author has been growing the bitter gourd plants in his home garden since 1973. Until 1980, this plant was completely free from all insect pests. During the 1980 growing season, occasionally a plant was found to wilt and die from near its base. In 1981, more plants started to wilt and an examination showed that a borer was attacking the plants. During 1982 and 1983 there was a steady increase in the number of plants attacked. Since 1982, an occasional fruit also has come under attack. It appears that the bitter gourd plant has become a preferred and probably a new host of this insect pest.

The Effects of Sevin XLR® on Nurse and Field Honey Bees. Gene Kritsky, Department of Biology, College of Mount St. Joseph, Mount St. Joseph, Ohio 45051, Cynthia K. Brown, Hamilton High School, Hamilton, Indiana 46742 and Peter A. Hippensteel, Department of Biology, Tri-State University, Angola, Indiana 46703.——As honey bees age, their contributions to the colony change. Newly emerged bees act as nurse bees and take care of cleaning the colony and feeding the larvae. After 15 days, the bees become field bees and leave the colony to collect nectar and pollen. Because insecticides are sprayed in the field, field bees are the first to come in contact with them. To determine if field bees and nurse bees have different susceptibilities to Sevin XLR® , a LD_{50} study was performed. The results indicate that field bees are more resistant to Sevin XLR®. The implications of this resistance to pest management programs that try to minimize bee kills suggest that applications made while field bees are foraging can effect the nurse bees in the hive.

Rocky Mountain Spotted Fever Tick Testing Program in Indiana. Robert R. Pinger, Ball State University, Stuart T. Walker, Ball State University, and Herald A. Demaree, Indiana Department of Natural Resources. In 1982 and 1983, a tick testing program was carried out in Indiana to determine the prevalence and distribution of spotted fever group (SFG) rickettsiae in ticks in Indiana. Ticks were submitted by sanitarians, veterinarians, employees of Indiana Department of Natural Resources and other cooperating citizens for testing at Ball State University's Public Health Entomology Laboratory. Ticks were tested for the presence of SFG rickettsiae by the hemolymph test and by indirect immunofluorescence. In 1982, 1492 ticks were submitted for testing from 80 counties in Indiana and two other states. The total catch comprised seven species of ticks: *Amblyomma americanum, Dermacentor variabilis, Haemaphysalis leporispalustris, Ixodes cookei, I. dentatus*, and *Rhipicephalus sanquineus*. Of the 1492 ticks received, 804 (54%) arrived alive and were tested. *Dermacentor variabilis* made up 96% of all the ticks tested. Forty-seven (5.8%) of the ticks tested were positive for SFG rickettsiae; all 47 were *D. variabilis*. In 1983, 1877 ticks were received for

testing from 84 counties and eight other states. In addition to the seven species received in 1982, an eighth species was identified, *Amblyomma macultatum*. *Dermacentor variabilis* constituted 94% of the ticks submitted. Of the 1877 ticks received for testing, 1443 (77%) arrived alive and were tested. Fifty-six (3.9%) of the ticks tested were positive for SFG rickettsiae. The positive ticks were identified as *D. variabilis* (54), *I. cookei* (1) and *I. texanus* (1).

Efficacy of Neem Extract Against Insects of Eggplant. DAVID K. REED and GARY L. REED, Fruit and Vegetable Insects Research Laboratory, Agricultural Research Service, USDA, Vincennes, Indiana 47591 and Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—Replicated experiments were conducted at the Southwest Purdue Agricultural Research Center where eggplants were treated with Neem Dust (20%), Neem Spray (0.2%) and cypermethrin (0.04 lb ai/A). Neem dust was relatively ineffective against Colorado Potato Beetle and Potato Flea Beetle. Neem spray was an effective as cypermethrin against both insects and both materials provided significantly greater control than the untreated. Neem, a derivative from the Neem tree, *Azadirachta indica*, may be useful in vegetable crop pest management.

The Effect of Prey Diet on Predation Efficiency of the Coccinellid, *Cryptolaemus montrouzieri* (Mulsant).

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Introduction

The physical conditions in greenhouses approach an optimum environment for the uncontrolled increase in populations of phytophagous insects. Once the insect is introduced, the greenhouse structure affords warm temperatures, high humidity and a physical barrier isolating the pest from the naturally occuring predators and parasites present in nature.

Effective chemical control of insects in greenhouse conditions when plant diversity is high is difficult. Compact growth habit, certain structural plant forms such as leaf sheaths, and dense foliage all prevent adequate application of the chemical to the entire plant. Failure to treat all surfaces, along with sub-lethal dosages due to improper application rates and pest diversity contribute to a serious problem encountered by greenhouses today—that of resistance and resurgence. The phenomenon of pesticide resistance followed by a rapid resurgence of the surviving insects can cause an actual increase in the pest population following chemical application as discussed by Doutt (1951).

Biological control of greenhouse pests through introduction of natural enemies offers a viable alternative to chemical controls.

This study began with the introduction of a predaceous coccinellid, *Cryptolaemus montrouzieri* (Mulsant) into a greenhouse to control a common species of mealybug *Planococcus citri* (Risso). The coccinellid was successfully introduced by Koebele into California from Australia in 1891 to control mealybugs in citrus orchards. Subsequent references in the literature also credit the beetle with successful population regulation. Immature soft scales (''crawlers'') have also been shown to be prey items (Hagen, personal communication).

During observations of the *Cryptolaemus* we discovered that both the adult and larval stages feed not only on the immature stages of the soft scales *Coccus hesperidum* L. and *Saissetia coffeae* (Walker) but were also found to be feeding on adults of both species. In addition both adults and larvae were observed feeding on an aphid *Aphis nerii* (Fonscolombe).

Experiments, using various prey items as a food source were devised to determine what effects, if any, a dietary change had on the life cycle, larval development and fecundity of the coccinellid.

Materials and Methods

Adult *Cryptolaemus* beetles, newly emerged from pupation were sexed (sexual dimorphism permits easy identification) and adults were placed in standard-sized glass petri dishes. The dishes were examined daily in all experiments. Fresh food sources and plant materials obtained from the campus greenhouse were supplied daily. Room temperatures of the laboratory averaged 76 °F during most of the study.

Summary of Experiments

The initial experiment was designed to establish the egg production potential of the adult beetle. Females were given a diet of mealybugs on *Coleus* leaves, a preferred

food source, and daily egg laying rates were recorded for each female. Eggs produced were removed and transferred to separate petri dishes. These were later examined in an attempt to determine % viability of eggs produced on the diet.

Females began laying viable eggs within 24 hours of insemination. The eggs are laid singly, in and around the mealybug egg mass, on plant parts and in the cracks and crevices of bark and stems. Egg laying initially appears to be triggered by a suitable substrate having a roughened texture, possibly perceived by the tarsi. The female then begins a searching pattern looking for both a food source and oviposition site. This latter behavior involves the use of the mandibles, antennae and ovipositor.

Given ample food *and* optimum substrate, the egg laying potential for these beetles is as high as 50 eggs per day, with the normal range 20-30.

A subsequent study dealt with rearing the beetle from egg to adult to determine dietary effects on the length of larval instars and the prepupal and pupal stagaes. The various instar stages were verified by the presence of the exuviae. The prepupal period is signaled by attachment of the fourth instar insect exuviae intact, to the substrate by means of a fluid secreted by an anterior abdominal segment. The actual pupal stage was considered to begin when larval segments could no longer be distinguished on the ventral portions of the body.

Three groups of insects were used in this study and each given a different diet. The results showed that the larval-pupal development in number of days was 8% less on a mealybug—*Coleus* diet as compared to a mealybug—oleander diet and 10% less than on an aphid—oleander diet.As the preceeding adults emerged from pupation, they were mated and again divided into three groups. This time we analyzed the effect of prey species on the mean number of days until production of the first egg by the *Cryptolaemus* female. Results of the three diets presented, showed that the mealybug—*Coleus* diet stimulated first egg production in 7 days; mealybug—oleander in 10 days and aphid—oleander in 25 days.

Simultaneously the eggs produced by each group of females were counted, recorded and removed from the various dishes. The results of this study showed that the mean number of eggs per day as the result of a mealybug—*Coleus* diet was approximately three times greater than the production based on a mealybug—oleander diet and fourteen times greater than that derived from an aphid—oleander diet.

Conclusion

One of the difficulties encountered in use of a predatory insect as an agent of pest control, is that near eradication of the host, in this case mealybugs, is followed by the disappearance of the predator. This necessitates reintroduction of the natural enemy. The significance of the results our experiments show is that during periods of time when the predatory beetle has reduced the population of mealybugs to very low levels, an alternate food source of aphids would sustain the predator until levels of mealybugs again increased.

Jamestown Canyon Virus: Vector-host Studies in Northern Indiana

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Introduction

Jamestown Canyon virus (JCV), a subtype of Melao virus of the California serogroup (Bunyaviridae: *Bunyavirus*), was first isolated from *Culiseta inornata* mosquitoes in Colorado in 1961 (16). Extensive studies conducted in Wisconsin and Maryland subsequently have implicated the white-tailed deer (*Odocoileus virginianus*) as the primary, and perhaps exclusive, vertebrate host of JCV (9, 10, 11, 12, 19). More recently, JCV has been implicated as an etiologic agent capable of producing meningitis and encephalitis in humans (3, 5).

Serological surveys have indicated foci of JCV infection in Indiana residents, particularily in the northern third of the state (4, 6). These investigations have prompted an extensive investigation of the ecology of JCV including that of the vertebrate host and any hematophagous arthropods potentially capable of transmitting JCV between deer and/or humans. Our primary study site is the Kingsbury State Fish and Wildlife Area in LaPorte County, Indiana. An earlier report (1) detailed the seasonal succession of hematophagous Diptera collected there in 1982 and the methods used to collect these arthropods. This report summarizes the 1983 mosquito and tabanid collections and two years of serological surveys of the Kingsbury deer herd.

Materials and Methods

Study Site: The Kingsbury State Fish and Wildlife Area, regulated by the Indiana Department of Natural Resources (IDNR), is a site with extensive areas of oak woods, open prairies, and marshlands that provides ideal habitats for a variety of hematophagous Diptera. This area also is an excellent habitat for the deer herd estimated to number 2000 head (7). During the annual deer hunting season, hunters are required to check in and out of the IDNR headquarters located on the property. This requirement greatly aided in obtaining samples for our serological surveys.

Deer Blood Sample Collection: Blood samples were collected in 1981 and 1982 both from pooled blood in the body cavity of field-dressed deer at the Kingsbury check station and by hunters at the kill site. Deer hunters entering Kingsbury were issued 7 cc blood collection tubes and participated in the serosurvey by collecting fresh blood as they field-dressed their deer. Blood samples were collected daily in this manner and refrigerated several days until transported to the laboratory for serological analysis. Blood samples were centrifuged in a refrigerated centrifuge at 4 °C for 15-30 minutes at 2000 x G; supernatant sera were aliquoted into individually labeled 1 dram glass screw cap vials. These sera were held at 4 ° C until serologically tested several days later.

Deer Age and Sex: Age of harvested deer was determined by Kingsbury IDNR personnel at the check station using standard tooth eruption and wear techniques (17). Three age groups were established: fawn deer (0.5yr) included only those animals determined to be less than 1 year old, 1.5 yr animals included only those determined to be older

than one year but less than two years, while the ≥ 1.5 yr group included all adult deer. Sex was readily determined by the IDNR personnel (17).

Viruses: Three reference viral antigens were used in the serological tests: JCV and trivittatus virus (TVTV) were obtained from the reagents bank of the Vector-Borne Diseases Division of the Centers for Disease Control at Fort Collins, Colorado. The La Crosse virus (LACV) used was an Indiana isolate (15) that is very closely related to the prototype LACV as determined by the oligonucleotide fingerprint technique (13).

Mouse Hyperimmune Ascitic Fluids: Hyperimmune ascitic fluids (HAFs) were prepared in 6 week old albino mice[1] using the JCV, LACV, and TVTV stock antigens according to the method of Tikasingh *et al.* (18). The HAFs were used as known positive controls in all serological (neutralization) tests and as reference typing antisera for virus isolations.

Cell Culture: A continuous cell line of African Green Monkey kidney (Vero) was used for all neutralization tests. Cells were cultured in Medium 199 supplemented with Earle's salts, 10% (heat-inactivated) fetal bovine serum, and antibiotics (200 Units of potassium penicillin G, 200 mg of streptomycin sulfate and 250 mcg of Fungizone per ml of media) at 37 °C in a 5% CO_2 atmosphere. This diluent was used throughout the study.

Neutralization Tests: All deer sera were initially diluted 1:8 in M-199 diluent and heat-inactivated at 56 °C for 1 hour. Antibody titers were determined using the microtiter serum dilution neutralization test (SDNT) and the three viral antigens in a manner previously described (6, 14). A virus test dose of 100 median tissue culture infectious doses (100 $TCID_{50}$) per 0.025 ml was used as well as a Vero cell suspension of 30,000 cells per ml for all antibody determinations. All SDNTs were done in 96-well flat-bottomed LINBRO® plastic trays[2]. Antibody titers were reported as the highest dilution showing less than 50% cytopathic effects after a 5 day incubation at 37 °C in a 5% CO_2 atmosphere. If the serum neutralized more than one virus but failed to neutralize another by a 4-fold or greater titer difference, then that serum sample was considered as evidence of a California group infection only.

Hematophagous Diptera Collections: Collections in 1983 were made in a manner similar to that described for the 1982 seasonal succession study (1) with several exceptions. In 1983 the resting boxes were not used nor were human-bait collections made. We did include a new type of trap, a 10′ x 12′ screen house of the type used to cover a picnic table, baited it with 10 pounds of dry ice and erected two plywood life-sized deer silhouettes inside. All hematophagous Diptera were handled and processed for virus isolation as described earlier (1).

Results

A total of 229 deer sera were serologically tested by SDNT in 1981 and 1982 (Table 1). Fawn deer had an average 4.8% antibody prevalence to JCV while the 1.5

TABLE 1. *Antibody prevalence to Jamestown Canyon virus in white-tailed deer at Kingsbury State Fish and Wildlife Area in 1981 and 1982.*

Year	Number Tested	Percent Antibody Prevalence by age group			
		0.5 yr	1.5 yr	≥ 1.5 yr	All ages
1981	109	4	81	82	49
1982	120	5	62	68	37

[1]ICR strain, Harlan Industries, Indianapolis, IN
[2]LINBRO® , Flow Laboratories, McLean, VA

yr old group averaged 70.1%; all adult deer averaged 75.6%. The rate of seroconversion in the 1981 fawn cohort between 1981 and 1982 was 58%. While there was no significant difference in antibody prevalence between fawn deer sampled in 1981 vs. 1982, there *was* a significant difference ($p < 0.05$) between the 1.5 yr groups sampled both years and between all adult animals both years ($p < 0.05$).

Collections of hematophagous Diptera, particularily the early spring (snow-melt) mosquitoes *Aedes stimulans* and *Aedes sticticus*, varied from 1982 to 1983 as did *Aedes vexans* (Table 2). Many more *Aedes cinereus* and *Aedes canadensis*, two other early spring species, were also taken in 1983 than in 1982, however, their numbers were much less than those of *Ae. stimulans* and *Ae. sticticus*. Collections of tabanids (deerflies and horseflies) were also greater in 1983 than in 1982 (Table 3).

Discussion

The results of the two year serological survey of white-tailed deer harvested at Kingsbury demonstrate a high level of deer exposure to JCV in that area of northern

TABLE 2. Record of mosquitoes collected during seasonal succession studies at Kingsbury State Fish and Wildlife Area in 1982 and 1983.

Species	Number of specimens collected	
	1982	1983
Aedes		
abserratus	6	
canadensis	3	119
cinereus	25	326
excrucians		1
sticticus		2509
stimulans	143	10104
triseriatus/hendersoni	46	72
trivittatus	5507	2083
vexans	6216	38091
species*	147	28
Anopheles		
punctipennis	24	54
quadrimaculatus	55	116
walkeri	19	1
species	3	
Mansonia		
perturbans	1029	1567
Culex		
pipiens/restuans	658	369
salinarius		1
tarsalis		2
territans	281	221
species	50	
Culiseta		
inornata	2	3
morsitans	5	
minnesotae	7	
species	1	
Psorophora		
ciliata	1	5
ferox		16
varipes		1
Uranotaenia		
sapphirina	113	16
Totals:	14,341	55,705

* Identification to species was not possible.

TABLE 3. Collections of Tabanidae at Kingsbury State Fish and Wildlife Area, LaPorte County, Indiana in 1982 and 1983.

Species	Total Number Collected	
	1982	1983
Chrysops		
callidus	1	12
cincticornis	4	16
cuclux	1	
frigidus	1	
indus	2	2
niger	2	90
univittatus	4	15
vittatus	1	17
species*		12
Hybomitra		
epistates	22	47
lasiophthalma	89	66
species	1	
Tabanus		
americanus		3
atratus	3	7
limbatinevris		4
lineola	65	961
marginalis	2	2
pumilus	10	13
quinquevittatus	9	17
similis	41	178
trimaculatus	4	19
vivax	129	768
species	25	
TOTALS:	416	2,249

* Identification to species was not possible.

Indiana. Earlier studies elsewhere had indicated that deer are sensitive indicators for JCV infection and that they may be important amplifiers or reservoir hosts for that virus (8, 10, 11, 12, 19). This study supports those earlier findings and helps elucidate an additional key step in the natural cycle of JCV, that of providing susceptible vertebrate hosts each season.

DeFoliart *et al.* (2) isolated JCV from naturally infected late spring and early summer *Aedes* mosquitoes and tabanids at a time that virus apparently was circulating in deer in Wisconsin (8). Additionally, Wright and DeFoliart showed that a variety of these late spring and early summer mosquitoes fed on fawns (20). Thus it seems reasonable to assume that fawn deer would also be fed on by these and other infected mosquitoes (and tabanids?) that apparently transmit virus to adult deer.

However, Issel *et al.* reported lower antibody prevalence rates in fawn deer in Wisconsin and speculated on three possible explanations (11): 1) a sampling error based on low numbers of fawns sampled, 2) the fawns were not exposed to the virus, and 3) the fawns were protected by maternal antibody against infection. Since less than 10% of their sample (50/587) were fawn deer, a sampling error seemed plausible. However, 45% (103/299) of the deer in this study were fawns and similar results were seen at Kingsbury both years. This study thus confirms the third alternative, that fawns are protected from infection, presumably by maternal antibody. Maternal antibody that is colostral in origin is known to persist in fawns for 8 to 23 weeks (a mean

of 19 weeks) and can protect them from a primary JCV infection (9). These fawns would then contribute to the pool of susceptible vertebrate hosts the following season. The high antibody prevalence rates in adult does provides a high rate of protection the following year to their new-born fawns and explains the low rate in fawns. Thus the natural cycle of JCV in northern Indiana, and probably elsewhere, is assured numerous susceptible vertebrate hosts each season.

The significantly lower rate of antibody prevalence in the adult animals in 1982 vs. 1981 is perhaps explained by the climatological conditions and the resulting mosquito populations. Populations of spring *Aedes*, including *Ae. stimulans* and *Ae. sticticus* and others, were abundant in the spring of 1981. The floodwaters resulting from snowmelt assured suitable aquatic habitats and the pools of water persisted for some time. However, in 1982, the snow melted rapidly, pools filled with water and these spring species hatched. Then a period of unseasonably cool and dry weather set in, the pools dried up and very few adult mosquitoes emerged. It is presumed that these early spring *Aedes* are the primary vector(s) of JCV and a reduction in their spring populations then might result in a significant decrease in the seroconversion rate between 1981 and 1982 deer cohorts, and indeed this is what we observed. With the very large populations of these mosquitoes collected in 1983, it will be interesting to see if the antibody prevalence rate in the 1.5 yr cohort increases significantly over that seen for 1982; if so, it will confirm in part this hypothesis.

Collections of tabanids were much greater in 1983 than in 1982 due primarily to the large numbers of *Tabanus lineola* and *Tabanus vivax* trapped (Table 3). While collection numbers of other species increased or decreased between 1982 and 1983, it appears that the large numbers of *T. vivax* we collected probably resulted from use of the tent trap as 98.9% of the total were obtained with that method and only a few specimens were taken in the DeFoliart-Morris trap.

A single isolate of TVTV was made in 1982 from a pool of 50 *Aedes trivittatus* female mosquitos collected in August. This is only the fourth time that this virus has been isolated in Indiana (15). Previously, a single yearling deer was found to be seropositive for antibodies to LACV at Kingsbury (4). Thus all three California serogroup viruses are apparently circulating in the Kingsbury area; however, JCV is by far the most important from the standpoint of vertebrate infection.

Acknowledgments

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Interspecific Relationships among Three Species of Milkweed Beetles (*Tetraopes*: Cerambycidae)

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There recently has been considerable debate over the role of interspecific competition in the structuring of animal communities (8, 10, 13, 19, 31, 32). Some ecologists have considered competition as a relatively unimportant influence on community organization (2, 14, 20, 25, 26, 27, 29, 30, 34, 35, 37, 19). This view is one which has been traditionally espoused by insect ecologists. The consensus is that the structure of insect populations does not meet many of the assumptions of competition theory, most important of which is the fact that insect populations rarely occur at equilibrium (27). Habitat complexity, habitat heterogeneity, and dispersal (7, 15, 9, 23), and predation and parasitism (19) all act to severely limit insect populations. The combined effect of these factors is to greatly minimize the influence that interspecific competition has on the organization of insect communities (16).

These caveats do not appear to apply to the milkweed beetles of the cerambycid genus *Tetraopes*. These beetles complete their entire life cycle on various species of milkweed (Asclepiadaceae), with the adults congregating on the leaves and inflorescences to feed and mate, and the larvae feeding and overwintering in the milkweed root (4). No parasites of *Tetraopes* have been reported (4), and predation is rare (pers. obs.). The beetles apparently sequester cardenolides from the milkweed sap, which makes them highly distasteful to avian predators (17). Milkweeds are perennials and tend to occur in more or less discrete patches. Adult *Tetraopes* move infrequently between patches (18).

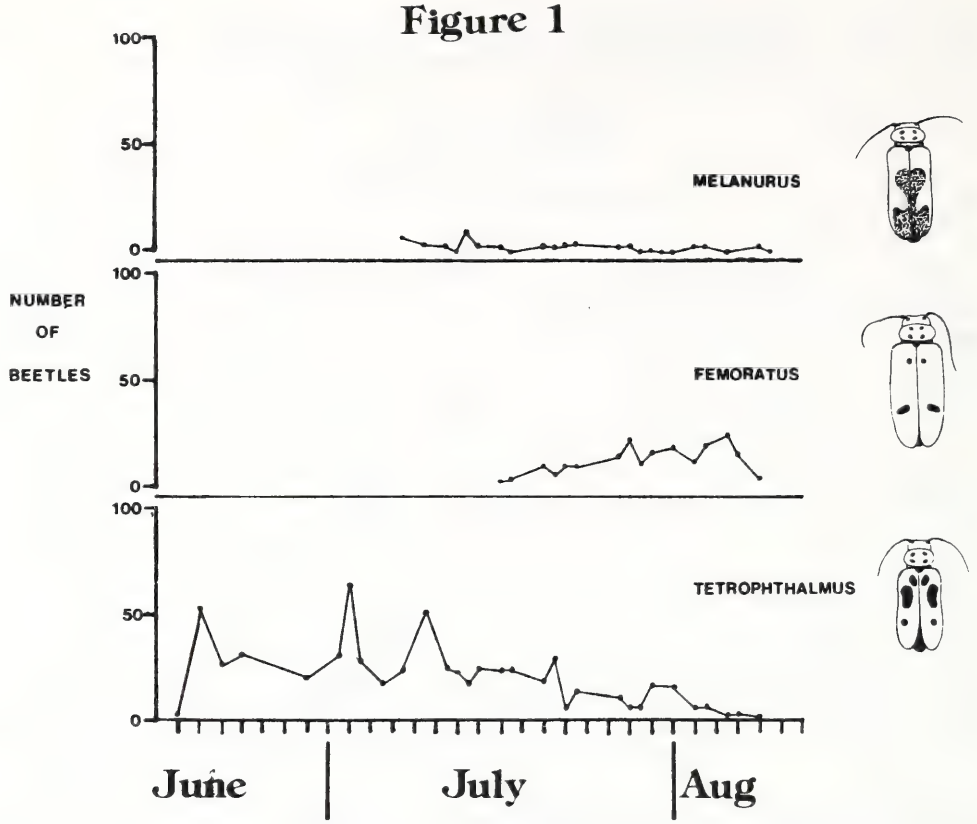
Chemsak (4) notes that when two sympatric species of *Tetraopes* utilize the same species of milkweed as the host-plant one of the *Tetraopes* species is decidedly less abundant than the other. Similarly, when two sympatric species of *Tetraopes* utilize different host-plants the two *Tetraopes* species occur with equal abundance. The depression of the population growth rate (r) or the carrying capacity (K) of one species in the presence of another, ecologically similar, species has been considered indirect evidence for interspecific competition (12). The purpose of this study was first to determine whether or not direct evidence for interspecific competition between species of *Tetraopes* could be obtained from field data, and, if so, to determine its importance in the dynamics of the *Tetraopes* guild.

Methods

Field work was done on a 100 m x 100 m study plot located in eastern Monroe Co., IN, from 16 June 1981 to 10 Aug 1981. The study plot included 420 *Asclepias syriaca* and 83 *A. tuberosa* plants, with *Solidago* sp. and assorted grasses comprising the bulk of the ground cover. Three species of *Tetraopes* were present on the study area: *tetrophthalmus* (Forster), *femoratus* LeConte, and *melanurus* Schönherr. A fourth species, *quinquemaculatus* Haldeman, has been reported from Indiana (1), but was not present on the study plot.

Daily censuses were taken on the study plot, during which time the entire plot was examined for the presence of *Tetraopes*. For each beetle the following information was noted: 1) species of *Tetraopes*, and 2) species of plant on which the beetle was found.

Figure 1



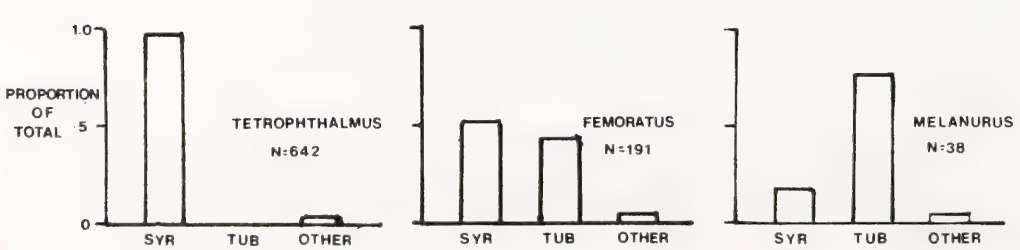
Results

Figure 1 gives the census data for the three species of *Tetraopes* present on the study site. *T. tetrophthalmus* was the most abundant species on the plot, first appearing on 16 June, when three individuals were noted. The peak count for this species was 64 on 2 July. *T. melanurus* was first noted on 7 July when six beetles were found, with a peak of nine individuals on 13 July. This species was the rarest *Tetraopes* on the site. The third species, *femoratus*, first appeared on 16 July. Two beetles were noted on this date, with the highest count being 24 on 6 Aug.

The distribution of the three species of *Tetraopes* on the host-plants is presented in Figure 2. *T. tetrophthalmus* specialized on *A. syriaca*, and *T. melanurus* on *A.*

Figure 2

Host Plant Preference



tuberosa. *T. femoratus* distributed itself nearly equally between the two milkweed speices. For all three species host-plant choice differed significantly from what would be expected if the beetles were distributing themselves randomly among the available *Asclepias* plants on the study plot (*tetrophthalmus*: $X^2 = 124.9$, df = 1, $p \ll .01$; *femoratus*: $X^2 = 98.6$, df = 1, $p \ll .01$; *melanurus*: $X^2 = 103.5$, df = 1, $p \ll .01$).

From the census and host-plant data, niche breadth values were calculated using the formula:

$$B_{ij} = \frac{1}{\Sigma P_{ij}^2}$$

where B_{ij} is the niche breadth of species j on resource state i, and P_{ij} is the proportion of species j on resource state i (21, 24). This value was standardized, resulting in a range of 0 to 1.0 for the niche breadth values. A value of 1.0 represents the largest possible niche breadth. Comparison of the niche breadths for the three species of *Tetraopes* on the two resource dimensions, host-plant and time (Table 1), shows that

TABLE 1

	Niche Breadth	
	Host-Plant	Time
tetrophthalmus	0.36	0.65
femoratus	0.74	0.40
melanurus	0.54	0.28

for all species a wide niche breadth along one resource dimension is complimented by a relatively narrow niche breadth along the other

The amount of niche overlap between species pairs was calculated using the formula:

$$O_{jk} = \frac{\Sigma P_{ij} P_{ik}}{\sqrt{\Sigma P_{ij}^2 \Sigma P_{ik}^2}}$$

where O_{jk} is the niche overlap between species j and k, P_{ij} is the proportion of species j on resource state i, and P_{ik} is the proportion of species k on resource state i (5, 24). The overall niche overlap is merely the product of the overlap values for all the resource dimensions (28). Two species whose niches totally overlap will have an O_{jk} of 1.0. The niche overlap values for the three pairs of *Tetraopes* species are presented in Table 2. For these species pairs overlap values are high on one resource dimension and relatively lower on the other, with the overall niche overlap between species pairs being small.

Finally, competition coefficients can be calculated for the species pairs using the index of MacArthur and Levins (22):

$$\alpha_{ij} = \frac{\Sigma U_{ih} U_{jh}}{\Sigma (U_{ih})^2}$$

where α_{ij} is the effect of species j on the population growth rate of species i, U_{ih} is the number of individuals of species i utilizing resource state h, and U_{jh} is the number

TABLE 2

	Niche Overlap		
	Host-Plant	Time	Overall
tetrophthalmus vs *femoratus*	0.78	0.24	0.19
femoratus vs *melanurus*	0.79	0.29	0.23
melanurus vs *tetrophthalmus*	0.23	0.42	0.10

of individuals of species j utilizing resource state h. α values of less than 1.0 indicate that intraspecific competition is more important than interspecific competition. From the Lotka-Volterra competition equations it can be shown that in order for two species to coexist the following inequalities must be true:

$$K_i < K_j/\alpha ji$$
$$K_j < K_i/\alpha ij$$
$$\text{or: } \alpha ji \bullet \alpha ij < 1$$

where K_i and K_j represent the carrying capacity for species i and j, respectively (12, 28).

The competition coefficients and their products for the species pairs are given in Table 3. In all three cases the products of the α's are well below the critical value of 1.0.

Discussion

The preceeding analysis suggests that interspecific competition does not play an important role in the organization of *Tetraopes* communities, at least with regards to adult populations. For the two resource dimensions, host-plant and time, the three *Tetraopes* species were found to behave as specialists on one resource dimension, and as generalists on the other, with the resulting overall niche overlaps being quite small. This is a pattern similar to one found by Uetz (33) in a guild of wandering spiders.

TABLE 3

	Competition Coefficients		
	α_{ij}	α_{ji}	$\alpha_{ij} \bullet \alpha_{ji}$
tetrophthalmus vs *femoratus*	$\alpha_{tf} = 3.29$	$\alpha_{ft} = 0.16$	$\alpha_{tf} \bullet \alpha_{ft} = 0.53$
femoratus vs *melanurus*	$\alpha_{mf} = 3.1$	$\alpha_{fm} = 0.17$	$\alpha_{mf} \bullet \alpha_{fm} = 0.53$
melanurus vs *tetrophthalmus*	$\alpha_{tm} = 0.01$	$\alpha_{mt} = 4.9$	$\alpha_{tm} \bullet \alpha_{mt} = 0.05$

In this instance niche divergence along at least one resource dimension was found to occur, allowing potentially competing species to coexist.

The question still remains as to the cause of the differences in relative abundances shown by sympatric species of *Tetraopes* utilizing the same host-plant reported by Chemsak (4). Chemsak also notes that in the midwest, near the eastern extent of the range of *T. femoratus, T. tetrophthalmus* is always the more abundant species (36, 11), but the situation is reversed farther west near the western extent of the range of *tetrophthalmus* (4). Such a reversal of relative abundances may be expected to occur if individuals near the edge of the species' geographic range, and presumably near the biotic limit of the species, are less efficient competitors.

Interspecific competition may still be an important influence on *Tetraopes* communities, not during the adult stage, as this study suggests, but rather during the period of larval development. One aspect of *Tetraopes* biology which has not been investigated is the effect that different levels of cardenolides have on the development of *Tetraopes* larva. *Asclepias* plants vary in their relative cardenolide content (3, 6), and it is possible that not all available milkweed roots are equally suitable for the development of larval *Tetraopes*. If this is true, the larval period may be a time of intense intra- and interspecific competition for these insects.

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Insects and Other Arthropods of Economic Importance in Indiana in 1983

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Introduction

The 1983 Indiana year from January to October readily divides into 3 climatic "seasons". The first three months (January-March) were warmer and drier than usual, averaging (in Indianapolis) from 3 - 5 degrees (F) warmer than the mean and with less than half the normal precipitation at least during the first 2 months. April ushered in the second "season" with cool, wet weather that delayed planting and slowed development. The third "season" starting about mid-June, brought higher than normal temperatures. Worse still, surface soil moisture, characterized as surplus through May, regressed to mostly adequate through mid-July, to mostly short for the rest of the summer. As an indication of the impact of the drought and heat, 13% of the 7500 corn stalks examined during September and October through most of the state were barren; the dry year of 1980 figure was only 5%. Dry weather seems to increase the incidence of smut in corn. Nine percent of the 7500 stalks had at least some smut galls, and 1% of the ears were supplanted entirely by smut. (The 1980 galls were however generally much larger.) Aflatoxin, produced by the fungus *Aspergillus flavus*, was found to be present in about 3% of the some 500 fields surveyed, also higher than normal.

A second factor impacted the 1983 yield of corn and wheat. The Federal government, in order to cut production, offered growers grain if they would idle acres—the payment-in-kind (PIK) program. About 2,600,000 acres were idled in the corn program (about 40% of the 1982 acres harvested) and 210,000 acres in the wheat program, about 19% of the 1982 crop. PIK acres were to be planted to a cover crop, and if that crop was sorghum, oviposition by corn rootworms might necessitate crop protection measures in 1984. There were growers who planted nothing and did little to control the weeds. These may have weed problems as well as insect problems in 1984. The only insect consistently observed in numbers in PIK acres was the corn flea beetle (*Chaetocnema pulicaria*).

Corn and Small Grains

In 1982 it was estimated that insecticides for the control of the western corn rootworm (*Diabrotica virgifera*) and the northern corn rootworm (*D. barberi*) were used on about 40 % of the corn planted. This year when given the opportunity to idle acres it would seem wisest to idle corn-on-corn acres. If that were possible in all instances the PIK program would have reduced insecticide usage by 40%. No reliable data are available at this time on insecticide usage in 1983. The western corn rootworm both because of its numbers and because there was less moisture in the soil to compensate for the loss of roots was probably more harmful to corn than last year.

The first first-instar of the western corn rootworm was collected 13 June in Tippecanoe Co. A prepupa was collected in Parke Co. on 22 June and the first adult was reported there on 5 July. It is probably that adults were present earlier because all reports at this time were of multiple beetles in each field. In the annual survey of adults, which was conducted at the end of July and the beginning of August—before the migratory flights begin—an average of 0.97 beetles/stalk was counted, the highest average since 1977, the first year of the survey for this insect. Four districts

averaged more than 1 western corn rootworm beetle/stalk (NC, C, SW, SE), a record. Three counties (Sullivan, Jennings and Decatur) averaged more than 2 beetles/stalk, also a record. The counts this year were probably more accurate than in previous years; the extremely hot and dry weather forced the beetles into crevices they were reluctant to leave, resulting in a much more sedentary population.

Counts of the northern corn rootworm in July and August indicated a state average of 0.07 beetles/stalk, half last year's number.

A total of 14,473 specimens of both species was collected on 10 sticky traps in a treated corn field in Tippecanoe Co. from 27 June to 19 September, as compared with 17,366 from 11 Jun to 23 September in 1982. The ratio of westerns to northerns was 92:8.

The reduction by 40% of corn acreage would not have affected this year's counts which were mostly pre-migratory. Migration later was limited to 60% of the normal acreage which should result in a concentration, i.e., heavily infested fields next year, but fewer of them, given normal oviposition.

Pupae of the European corn borer (*Ostrinia nubilalis*) were seen by 11 May and 2 males were taken in a BL trap on 20 May (Daviess Co.) First generation moths flew from mid-May to mid-July; a Posey Co BL trap collected more than 200/week during the whole month of June. Second generation moths flew from mid-July through August (trapping stopped then) and in very large numbers especially in the north of Indiana. A trap in Jasper Co. collected 1000-plus moths/night for a few nights. Statewide at season's end live larvae/100 stalks averaged 84.2. Except for the northern fourth of the state the average would not have exceeded 50/100 stalks; NC counties averaged 250/100, NE counties averaged 187 while the counties from Montgomery north averaged 145. The 20 year average for the state is 62 larvae/100 stalks. An Elkhart Co. field had an average of 950 larvae/100 stalks, the highest observed in the 300 fields surveyed.

Only 12% of the 7500 stalks surveyed in the fall showed signs of having hosted the corn leaf aphid (*Rhopalosiphum maidis*), and more than half of those had sub-economic populations. This aphid developed to huge numbers in the dry spell of 1980, but failed to do so this time.

Bird cherry oat aphids (*R. padi*), which prefer rather moist environments, were almost absent from corn fields this year, and were no problem in wheat.

Armyworms (*Pseudaletia unipuncta*) and black cutworms (*Agrotis ipsilon*) were only minor problems affecting probably fewer than 1000 acres this year. Neither the corn earworm (*Heliothis zea*) nor the fall armyworm (*Spodoptera frugiperda*) were common in ear tips of field corn this year.

Hessian fly (*Mayetiola destructor*) experienced a good winter and spring, and growers who planted non-resistant varieties of wheat sometimes sustained heavy losses. The data from the only survey made (by the Agriculture Research Service of the USDA, the Indiana Crop Improvement Association and Purdue's Department of Entomology) of this insect indicate the opposite; mean percent infestation for all varieties fell to 0.9%, mean puparia/100 stems 1.1, and only 21% of the fields surveyed were infested, all down from 1982. The reason for the low levels in a year favorable for the fly: only the fields of certified growers are surveyed. They are more likely than the rest to sow seeds with the H6 gene which is highly resistant to the fly, producing a biased sample. It does indicate however that the H6 gene is still an effective protection.

Forage Legumes and Soybeans

An estimated 10,000 acres of soybeans may have been treated to prevent losses

by the Mexican bean beetle (*Epilachna varivestis*), and there may have been some losses in untreated fields especially in the Parke and Montgomery Co. areas. Probably only a few of the treated acres were actually in danger of economic losses due to this insect. As a whole, even though adults were seen in soybeans far beyond their usual range and though, what with the warm winter, populations should have been large, Mexican bean beetles were only a minor problem in 1983.

The first adult of the season swept from alfalfa was collected 4 May in Jackson Co. Eggs were seen on 13 June in Parke Co. and on 16 June in Montgomery Co., where adults numbered 1/meter. Hatching was slow; no larvae were present by 1 July in any field except a Vigo Co. field with an unusually early and for this year heavy population; large larvae were present on 5 July. Pupae were present with occasional new adults by 20 July in Parke Co. Then came the hot days. Pupae, fastened to higher leaves, suffered the highest mortality, but larvae and pupae were also affected, and the populations collapsed.

There were scattered reports of pod feeding by the bean leaf beetle (*Certoma trifurcata*) adults late in the season but these seldom penetrated to the seed and were generally of little consequence.

One of the consequences of the hot, dry weather was the build-up of the twospotted spider mite (*Tetranychus urticae*) in soybeans. First observed in Clinton Co., they were soon reported from scattered locations all over the state. Edge rows were first attacked, and in most instances little more than the edge rows were affected so that treatment of more of the field was seldom warranted.

Adults of the painted lady (*Cynthia cardui*) were first seen in more than the usual numbers in alfalfa fields as early as the first week of May in the WC, SW and SC districts. What appeared to be new second generation adults were seen early in July. There were many reports of this species feeding on soybeans, and adults appeared in large numbers expecially on roads separating 2 soybean fields. In one instance, counting only those killed or immobilized by vehicles in a 15-inch band next to a black-top highway, adults averaged 1/foot. Again, like the twospotted spider mite, they were the source of many inquiries but were of little economic consequence.

The alfalfa weevil (*Hypera postica*) larvae in alfalfa increased in numbers from about 25/100 stems on 7 March to about 245/100 stems on 10 May, or, based on the percent of stems infested, from about 12% to about 80%, in the SW and SC districts. During that time the alfalfa grew from an average of 4 to an average of 27 cm. Counts dropped rapidly after that, and the alfalfa quickly recovered. Treatment of infested fields was sporadic and in most instances questionable. The cool wet spring slowed alfalfa development, reducing the yield of the first cutting. The second cutting on well managed fields was generally good.

Potato leaf hopper (*Empoasca fabae*) was an economic pest on second and subsequent cuttings and even necessitated treating some soybean fields. Because of drought, alfalfa yields were so poor after the second cutting that few growers bothered to treat, except in the northern part of the state.

Vegetable Insects

Corn earworms early in the season for this species heavily infested untreated sweet corn grown for processing. Later in the season the same species was economic in commercially grown tomatoes.

The bean leaf beetle was a serious pest in some areas of beans in home gardens.

Striped cucumber beetles (*Acalymma vittata*) were a serious pest of melons and cucumbers through much of the season, even to the extent of feeding on the rinds.

Most other garden pests were present, but not in remarkable numbers.

Fruit Trees

All of the data on fruit tree insects are based on catches in 5 pheromone traps in Knox Co. operated by Thomas Mouzin for the USDA. Only 249 male codling moths (*Cydia pomonella*) were collected during 1983. The range since 1976 runs from 211 to 1392, and the 7 year average (1976-1982) was 551. Moths were caught during every week from mid-May to early Oct, with only 1 clear-cut peak near the end of June.

The 1983 catch of the redbanded leafroller (*Argyrotaenia velutinana*) was 927, with 3 peaks, late April, early July and mid-August. The 7 year average is 1499, the range from 706 to 2941.

The year's catch of the Oriental fruit moth (*Grapholitha molesta*) totalled 1037. The 7 year average is 1844, the range from 426 to 3707.

The lesser peachtree borer (*Synanthedon pictipes*) total was 1591, less than half last year's. Pheromones have been used only 3 years to collect this insect; previously live moths provided the incentive.

The 1983 catch of the peachtree borer (*Synanthedon exitiosa*) was 289, somewhat above the 4 year average of 166.

No traps were in place this year to trap obliquebanded leafrollers (*Choristoneura rosaceana*).

Man and Animals

The following generalizations were provided by Medical Entomologist Michael Sinsko. Mosquito populations overall were down from normal, due to droughty conditions. With mosquito numbers down, the incidence of mosquito-borne diseases was also down. There were no confirmed cases of St. Louis encephalitis, and only 2 confirmed cases of LaCrosse encephalitis. The 7 cases of eastern equine encephalitis among horses in Elkhart and St. Joseph counties apparently were more or less of a spillover from a larger Michigan outbreak. Reports of fleas were about normal. House fly (*Musca domestica*) numbers were down. Reports of head lice (*Pediculus humanus capitis*) have been on the upswing during recent years and 1983 was no exception.

Horn fly (*Haematobia irritans*) and face fly (*Musca autumnalis*) numbers were about normal according to Ralph Williams, Purdue Veterinary Entomologist.

Beneficial Insects

The alfalfa weevil parasites *Bathyplectes anurus* and *B. curculionis* were reared from about 20% of the alfalfa weevil larvae from the NW, WC, C and EC districts, from about 34% of the larvae in the SW and 74% in the SC district. *B. anurus* was collected only, and usually predominated in counties south of Indianapolis. About 2000 larvae were reared; the NC, NE and SE districts were inadequately tested.

The red coccinellids collected on 10 sticky traps in a Tippecanoe Co. corn field are counted each year as a population estimate. The most common of these is *Coleomegilla maculata*; this year only 211 were collected. This number may be low because the field was harvested early and the traps were in place only 85 days as compared to the normal 100 or more. The ratio of *C. maculata*:*Hippodamia convergens*:*H. tredecimpunctata*:*Cycloneda sanguinea* was 67:14:1:18. The red coccinellids are also counted in the annual fall corn insect survey which examines 300 fields in 60 counties. This year there were—in the order listed in the ratio above—231:21:4:2, or in ratios, 89:8:2:1. These figures are about average.

Current Status of the Blue Wasp, *Chalybion zimmermanni* Dahlbom, in Southeastern Indiana

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ABSTRACT

It has been 15 years since the first recorded observation (1968) of *Chalybion zimmermanni* Dahlbom (Hymenoptera:Sphecidae) in Indiana and it seems appropriate to report its current status in the state. In the summer of 1983 *Chalybion z. zimmermanni* was found in five counties, for a total of 29 counties. All of these are south of the 40th parallel and within a band extending across the southern part of the state, reaching approximately 75 miles north of the Ohio river. Of 57 active nests found, 48 (84%) were in wood and 9 (16%) were in other holes. These included four in a plastic electric outlet, three in deserted nests of *Sceliphron caementarium* (Drury), and two in deserted nests of *Trypargilum politum* (Say). An aggregation of *Chalybion* sp. was found near Cedar Grove, Franklin county, on the south and west sides of a wellhouse. Cleptoparasitism at a *C. zimmermanni* nest was observed at the Franklin county site on 26 July.

Introduction

It has been 15 years since the blue wasp, *Chalybion z. zimmermanni* Dahlbom (Hymenoptera:Sphecidae) was first recorded in Indiana (1), and it seems appropriate to report its current status in the state. Previous observations have found this wasp in 23 counties (1, 2). Nests of this sphecid wasp are characterized by an inner, countersunk plug of mud taken from the nests of mud-carrying wasps such as *Sceliphron caementarium* (Drury) and *Trypargilum politum* (Say) and covered by a plug of uric acid gathered from the fecal matter (droppings) of birds or reptiles (1). All nests have been in man-made structures, and are provisioned with spider prey.

Another behavioral feature of the genus *Chalybion* is the formation of nighttime or inclement weather aggregations (3). These usually have been on the west sides of buildings or in protected places. In addition, the taking of prey previously captured by other insects, cleptoparasitism, has been reported for several genera in the Sphecidae, including the blue water-carrier, *Chalybion californicum* (Saussure) (4), but has not been reported for *C. zimmermanni*.

Methods

Observations were begun on 16 June 1983 and ended on 13 August 1983. The strategy was to drive through a county searching for older wooden barns, especially those near a water source such as a stream or farm pond. When such a barn was located, we asked permission of the owner or tenant to examine the interior for the characteristic uric acid plug of the *C. zimmermanni* nest. If these were found, the timber, post or other site was photographed and/or sketched. An ink mark was made on the uric acid as an aid in determining at a later date whether or not a nest had been opened.

Possible sites for aggregations were also sought and observations were made of active nests as they were being filled with spiders and plugged.

Results and Discussion

Chalybion z. zimmermanni nest sites were in five counties, Jackson, Jefferson,

Jennings, Scott and Shelby. A previously unpublished observation in Fayette county, plus earlier accounts (1, 2) brings the total to 29 counties. These are all south of the 40th parallel and within a band extending across the southern part of the state, and reaching approximately 75 miles north of the Ohio river. A total of 57 active nests was found with 48 (84%) in wood, and 9 (16%) in other holes. These included four in a plastic electric outlet, three in deserted nests of *Sceliphron caementarium* (Drury) and two in deserted nests of *Trypargilum politum* (Say). This compares with 80% in wood and 20% in other sites reported in 1971 (2). Equal time spent searching for nests north of U.S. Route 40 in Wayne county failed to reveal any nests. It seems that this wasp is not moving northward with any rapidity.

During observations at a farm near Cedar Grove, Franklin county, several *Chalybion*-type blue wasps were seen at an overhanging roof on a wellhouse. The wasps started to gather on the west and southfacing sides on a cloudy afternoon (16 June), and on the evening of 21 July a total of 40 wasps was counted at the same site.

Several active nests near Cedar Grove were under surveillance for several days, and female wasps were timed as they brought spider prey to their nests. The nests were in a wooden timber in holes approximately one inch in diameter. These were holes used for securing a piece of farm machinery with a metal pin. As one wasp brought a series of spiders to the nest, a second wasp took the spiders out of the nest, one by one. This occurred on 26 July, and on 27 July the cell had been refilled with spiders by 2:05 p.m., closed with the inner seal of mud by 2:12, and sealed with seven loads of uric acid by 4:09 p.m.

Conclusions

1. *Chalybion z. zimmermanni* has been found in 29 Indiana counties since it was first observed in the state in 1968, all below the 40th parallel and in a band approximately 75 miles north of the Ohio river. It seems to be staying within that band and not moving northwards.
2. Of 57 active nests recorded, 84% were found in wood and 16% in other materials, including four in a plastic electric outlet, and five in deserted nests of other wasps.
3. An aggregation of 40 *Chalybion* sp. was found on the south and west sides of a wellhouse near Cedar Grove, Franklin county.
4. Cleptoparasitism was observed at a *Chalybion zimmermanni* nest in a barn near Cedar Grove, Franklin county.

Acknowledgments

The assistance of a grant from the Earlham College professional development fund is gratefully acknowledged. Aid from the Toms Fund of the Joseph Moore Museum is appreciated.

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ENVIRONMENTAL QUALITY

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ABSTRACTS

Comparison of Exchange Rate of Quaternary Ammonium Ions on Various Cation Exchangers. P. C. CHIANG, Graduate Institute of Environment Engineering, National Taiwan University, Taipei, Taiwan, ROC, and ROBERT H. L. HOWE, Center for Advanced Biotech Information, West Lafayette, IN 47906.——A study was undertaken to evaluate the exchange rate of several quaternary ammonium ions, i.e. Benzyl Hexadecyl Dimethyl Ammonium Chloride (BHDAC), Hexadecyl Pyridinium Chloride, (HPC), and Lauryl Pyridinium Chloride (LPC), on the macroporous (Amb-200 and Amb-DP1) and gel structure (Dow-50-x8 IRC-84, and C-464) ion exchangers. The results of this investigation indicated that the rate-determining-step of these quaternary ammonium ions on the strong acid cation exchanger was particle diffusion controlled. The macroporous resin provided higher particle-diffusion coefficient than that of gel structure resins. A linear relationship between log Dp (Particle-diffusion) and Ω. (Limiting Equivalent Conductivity) equation for determining the Dp by measurement of Ω. for various quaternary ammonium ions.

Passive NO_2 Sampling in Indoor Environments. THAD GODISH, Indoor Air Quality Research Laboratory, Ball State University, Muncie, Indiana 47306.——Nitrogen dioxide (NO_2) levels were monitored in a variety of residential environments. Seven day average NO_2 concentrations were determined from exposed Palmes diffusion tubes. Residences were classified as to the presence/absence of a gas cooking range and the primary source of space heat. Residence categories included those with (1) gas cooking range, (2) gas/oil heat, (3) wood stove heat, (4) electric heat, and (5) steam heat. Median NO_2 concentrations were 35, 8, 15, 7, and 9 ppb respectively. Residences with a gas cooking stove irrespective of the source of space heat had consistently the highest level of NO_2 contamination. A population of residences in which wood was utilized as the primary source of heat were monitored to determine whether NO_2 levels could be related to outdoor temperatures which could be the primary determinant of fuel needs and combustion frequency, intensity, and duration. No correlation was observed between heating degree days, a measure of the 24-hour average outdoor temperature and the concentration of NO_2 indoors. A single residence with a gas furnace located in the basement level was monitored. Significantly higher levels were monitored in the basement level as compared to a first floor living level. Study results demonstrate that indoor contamination by NO_2 can be realted to combustion appliances used for cooking and space heating.

Lake Residential Sewage Disposal Effects on Ground Water Quality. PETER HIPPENSTEEL, Department of Biology, Tri-State University, Angola, Indiana 46703.——During the past five years well water samples have been analyzed from lake residential areas of Northeastern Indiana. These samples were tested for fecal and total coliform, phosphates, nitrates, chlorides, and conductivity. The concentrations of the

ground water samples were compared to soil types and well depth. Since all of the homes in the lake area have their own on-site septic system, sewage effluent is the most probable source of contamination.

Eleven percent of the wells sampled indicated various levels of contamination. Fecal coliform and nitrates were the most common contaminates. These ground water pollutants were most evident in shallow wells (less than forty feet deep) and the highly porous soil types.

As the lake residential areas become more intensively used with the building of multiple family housing, and the conversion of seasonal homes to permanent use, ground water contamination will increase drastically. These trends will require new approaches to on-site sewage treatment and continued monitoring of the ground water to assure reduction of ground water contamination.

The Presence of Transformation of Formaldehyde in Nature. ROBERT H. L. HOWE, West Lafayette, Indiana 47906.——The presence and transformation of formaldehyde in nature is discussed. The pathways of such transformation are presented. Some experimental data are reviewed. This study has reinforced strongly the prior views of many that the relatively low concentration of formaldehyde in nature does not necessarily mean the contamination by industrial discharge.

One simple illustration is:

$$(C{\cdot}H_2O)\,6 \rightleftharpoons 6\,HCHO$$

Other reaction pathways involving the transformation of formaldehyde also are discussed.

Evaluation of Muskmelon and Watermelon Cultivars for Damage Attributed to a Combination of Ozone and Sulphur Dioxide. GARY L. REED and DAVID K. REED, Fruit and Vegetable Insects Research Laboratory, Agriculture Research Service, USDA, Vincennes, Indiana 47591 and Department of Entomology, Purdue University, West Lafayette, Indiana 47907.——The melon crops of Southwestern Indiana developed considerable leaf injury in the forms of chlorosis, spotting, and early senescence of mature leaves during the 1983 season. The early senescence caused fruit of both muskmelon and watermelon to become sunburned or scalded and thus unmarketable. The disorder was identified as injury caused by ozone, sulphur dioxide, or the two in combination. Observation of muskmelon and watermelon cultivars indicated differential amounts of leaf injury which will enable the grower to select more tolerant plants for 1984. The observed differences also indicate a potential for breeding resistant cultivars.

Ozone and Hydrogen Peroxide Injuries to Green Plants

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Introduction

This paper is intended to present our literature search about the injuries to green plants by O_3 in the air. It also is a report to describe some field experimental work in the observation of O_3 and H_2O_2 droplets applied to green plants during the extremely dry and hot summer season of 1983.

Literature Search

Recently, much has been reported about the injuries to vegetation by ozone and other air pollutants (1). According to the reports by Middleton (2) and Richardson et al. (3), ozone probably has cased more injury to vegetation than any other air pollutant in the United States. There are considerable varietal and species differences in ozone sensitivity as observed by Brennen (4) and Davis (5). Generally speaking, the characteristic of specific injuries, as well as the extent of injury are greatly influenced by the type of plant, length of exposure, concentration of ozone, and other environmental conditions such as light, relative humidity, temperature, etc.

Ozone injury lesions include pigmented lesions, upper-surface and either surface bleaching, bifacial necrosis, or chlorosis. Severe injury results in tissue collapse and necrosis, and chronic injury appears as various amounts or degrees of chlorosis. Ozone injury may also result in retarding growth and reducing yield of many species of plants.

The most common acute symptoms of ozone injury is the small stipple or flecklike necrosis lesions visible on the leaf surface. These irregular shapes of a few millimeters diameter may be dark brown to black stipple and light tan to white fleck.

High light intensity during ozone exposure generally increases the sensitivity of the leaf tissues (6,7). Low light intensity during exposure to ozone can also cause extensive areas of the leaf to turn white or light yellow, apparently because the chlorophyll is bleached out but the tissue is not completely damaged.

Low concentrations of ozone for several hours of exposure may cause chlorosis of the oldest leaves of the plants. The chlorosis appears to be the same when leaves become senescent. Low level ozone exposure may also cause excessive development of red pigmentation, resulting in a red or purple color change of some leaves.

The location of injury with respect to the position on the leaf and the degree of maturity of leaves is frequently of significant diagnostic value. Injury is frequently limited to the upper leaf surface. When there is injury, it is usually intervenal since veins are relatively resistant to ozone and they may develop symptoms of injury only when it is severe (7). Leaves of 65-69% of their full size have been reported to be the most sensitive to ozone injuries, depending on the species.

Ozone concentrations of 0.13-0.17 ppm for 2,4,8 hours exposure time (8), 0.16-1.3 ppm for 4 hours (9), and 0.1-0.3 ppm for 4 hours (4) have been tested and reported in recent studies. All concentrations are in V/V. In fumigation experiments, 2-4 hours are usually required to cause injury to the most sensitive species (6).

Several paramaters can be used to measure ozone injury to leaves. For visible

1. White dots

2. Brown and white dots and sheen

FIGURES: 1 & 2. *Peroxide and* 0_3 (?) *injuries to oak (top) and grape (bottom) leaves in hot and dry weather.*

assessment of leaf injury, the number of injured leaves and the extent of leaf necrosis are used for making an estimate (10).

Field Experiments

Because little has been reported about the injury to green plants by hydrogen peroxide, we conducted field experiments by applying both O_3 water droplets and H_2O_2 water droplets to green plants separately for our own study of special interest (11,12). For O_3 study, we used ozonated water diluted to 0.3120 ppm water solution for spraying the droplets to various leaves by means of an air spray gun (30 liters per minute air to spray 1.0 liter O_3 water droplets per minute). For H_2O_2 water spray we used only a simple droplet spray devise using 0.5 ppm H_2O_2 water solution.

We began our field experiment in late July. The green plants were pin oak, soft cottonwood, and grape. During the period of study, there was no measurable rain fall and the temperature was 80 to 95 degrees F in day time and 70 to 77 degrees during the night. Some decolorization of all leaves sprayed was observed. White sheen and brown-yellow color changes were very visible (photos). Color changes were noted to have developed after 24 hours of a single spray (30 seconds exposure time to 0.3 ppm V/V O_3 in air). During the spray of O_3 water droplets, the person was totally covered with a clear plastic hood, and *no contact with any spray mist was permitted.* A breathing mask was also provided so that *no mist was inhaled.* The H_2O_2 concentration was 0.5 ppm prepared from standard 5.0% H_2O_2 solution.

Discussion

We used a simple aerosol spray device for producing the O_3 and H_2O_2 droplets on to leaves of oak, cottonwood, and grape in order to see if their possible injuries might look similar. We were also particularly interested in the environmental conditions such as temperature, sunlight, air moisture, wind velocity, and the time of contact or exposure. Unfortunately, throughout the entire length of experiment time, it was hot and bright-sunny during the day time. Practically, there was no precipitation during the entire period.

During the entire course of field experimentation and observation, we have noticed that the injuries by both 0_3 and H_2O_2 appeared to be very similar. Therefore, we wish to discuss here a little about the chemical reactions of O_3 and H_2O_2 transformations. According to the study the work performed by Rollefson and Burton (11), O_3 can be produced by O_2 and H_2O_2 through UV activation (1850 A range). In this reaction O_3 and H_2O_2 were produced. Interestingly enough, H_2O_2 was noted to be produced by green plants by the work of the senior author and many others (12,13,14). In other words, we have noted the following reactions:

$$H_2O_2 + O_2 \xrightarrow{UV} H_2O + O_3,$$
$$O_3 + H_2O \rightarrow H_2O_2 + O_2,$$
$$CO_2 + 4H_2O \rightarrow C{\bullet}H_2O + 2H_2O_2 + 2H_2O,$$
$$2H_2O_2 \rightarrow 2H_2O + O_2.$$

If all their findings are correct, it seems that there is a possibility that O_3 in the air might become H_2O_2 falling on to the leaf, and vice versa. Perhaps further experiments may enlighten us in the future.

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GEOLOGY AND GEOGRAPHY

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ABSTRACTS

Geological Conditions Related to Longwall Coal Mining, Pike and Warrick Counties, Indiana. C.T. HUANG and T.R. WEST, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.——Pennsylvanian coal-bearing rocks of the Spurgeon coal field, in southern Pike County and northern Warrick County, Indiana cover about nine square miles in the southeastern part of the Illinois Basin. Coal beds occur throughout the Dugger and Petersburg Formations, the most extensive and valuable one being the bituminous Springfield Coal Member V in the upper Petersburg Formation.

The feasibility of longwall mining is dependent on the geologic and mining conditions of the site. An assurance of a uniform thickness and continuity for coal seam V encourages the possibility of adopting the highly mechanized longwall mining methods. The successful operation of longwall mining is also dependent on the continuous and regular caving of the roof after coal removal. The thickness of the immediate roof is measured as the distance between the top of coal seam V and the first contact of sandy shale and gray sandstone in the cores. Based on the drill core strength, the evaluation of the caveability behavior shows that the immediate roof is classified as "fairly good/good, easy caving".

Laboratory Testing of Indiana Shales. C. W. LOVELL, Department of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.——Indiana shales may be used in fills, provided that the material properties have been properly assessed prior to construction. Necessary tests fall into three categories (1) durability classification, (2) degradability and other compaction responses, and (3) strength and compressibility in service.

The primary hazard is that of placing nondurable materials in large pieces as a rockfill. Such pieces will break down (slake) under service conditions, producing undesirable settlement, or even shear failure, of the fill. An indicator of the slaking tendency is afforded by the slake-durability test.

Nondurable shales must be thoroughly degraded and compacted in thin dense layers. Tests have also been developed to allow the appropriate construction control for this purpose. Finally, principal in-service properties of the fill may be predicted from laboratory tests which saturate compacted shale samples under simulated fill confinement.

The paper briefly describes the requisite laboratory testing.

Engineering Geological Evaluation of an Earth Rock Fill Dam, Greene-Sullivan State Forest, Indiana. IGNATIUS O. OKONKWO and TERRY R. WEST, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.——The earth-rock fill dam that impounds Reservoir 29 in Green-Sullivan State Forest has an active seepage zone in the right abutment area. The dam also has undergone severe erosion on the upstream face during high water levels, typically in spring.

Built in the 1930s and enlarged in the early 1960s, the dam was built without

engineering design and was not properly compacted in place (no standard specifications for compaction were considered). It also lacks a clay core or other impervious zone to resist seepage.

Construction material for the dam was obtained from cast over piles resulting from three episodes of mining. Coal extraction in this area has been from Pennsylvanian age rocks, consisting primarily of the Dugger formation, which is overlain and underlain respectively by the Shelburn and Petersburg formations. The Dugger Formation is composed mainly of shale, sandstone and limestone in alternating sequences with three distinct coal members, that is, the Hymera Coal Member (coal VI), the Bucktown Coal Member (coal Vb), and the Springfield Coal Member (coal V). Coal has been removed both by stripping and underground mining in this general area.

Stability of the dam apparently is related to 1) the engineering properties of these geologic materials which comprise it, 2) the mode of construction of the dam, 3) the ongoing seepage of acidic water from the upstream reservoir.

The last mined coal member contains abundant pyrites, and this was separated from the coal, by gravitational settling. Enormous piles of the separated material constitute the source of acidity in the upstream reservoir, as runoff from these piles feed directly into that reservoir. pH measurements in the upstream reservoir range from 3.0 to 3.5 and from about 4.5 to 5.0 in the downstream reservoir.

Deterioration of embankment material in addition to other factors, could be related to the reaction between the acid water and limey shale, limestone, and dispersive shale. Field and laboratory testing have been key factors in the performance evaluation of the earth rock fill dam. Input data obtained from these investigations will be utilized in a computer analysis (STABL Program) to determine the present stability condition of the dam.

Poor performance is likely to result from inadequate seepage control, upstream erosion of dam face and instability owing to the removal of fines from the dam by the seepage process (piping). A geophysical field survey (self potential and electrical resistivity methods) plus borehole data, hopefully will define areas of potential failure or piping. Remedial action may include all or some of the following: design of a spillway, rebuilding of the upstream face, stabilizing the toe area and placement of a toe drain on the downstream face.

Engineering geology studies continue on this project. Grants to provide some of the field expenses have now been received from the Indiana Academy of Science and the Indiana Department of Natural Resources, Division of Reclamation.

HISTORY OF SCIENCE

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ABSTRACTS

Theory and Practice in the Career of William Lowe Bryan: Preliminary Notes. James H. Capshew, Department of History and Sociology of Science, University of Pennsylvania, Philadelphia, Pennsylvania 19104.——William Lowe Bryan (1860-1955) perhaps is best remembered for his long presidency of Indiana University (1902-37). His career as a psychologist is less well known; most historians of psychology have either ignored, dismissed, or misinterpreted his work by removing it from its social and intellectual context. Bryan's deep concern with philosophical and educational issues was evident throughout his life, and was clearly reflected in his psychological research on human skill learning. By using his work in psychology as a key to his social and intellectual views, Bryan's life can be understood in its rich historical context. Like other psychologists of his era, including William James and G. Stanley Hall, Bryan sought to reconcile the claims of science with traditional moral and religious belief. By recognizing the legitimacy of various epistemological approaches, he avoided direct confrontation between religious, scientific, and philosophical positions. This pluralistic stance was evident in his multiple roles as philosopher, scientist, educator, and churchman. Not content with narrow laboratory experimentation, Bryan centered his psychological investigations on the learning of life occupations, with their complex habit patterns and value systems. Occupations, he believed, provided the basis for social stability and progress, and in a changing world with increasing occupational specialization and stratification, education was becoming correspondingly important. Thus Bryan arrived at an intellectually satisfying justification for his role as an educator, and found a personal mandate for developing the university's science curriculum and professional schools.

Archaeoastronomy and Ohio Hopewell. Ray H. Hively, Department of Physics and Astronomy, Earlham College, Richmond, Indiana 47374.——When European settlers first explored central Ohio, they discovered numerous prehistoric earthworks typically located in river valleys. Some of these earthworks were more extensive than Avebury and required an effort in design and construction comparable to Stonehenge. Altogether, more than one hundred Ohio sites involving large earthworks, many of them geometrically regular, were known by 1900. Two of the most striking examples of such sites were the circle-octagon earthworks near Newark, Ohio (the Newark works) and near Chillicothe, Ohio (the High Bank works). Both examples are notable for their large scale (the Newark works cover some four square miles) and their remarkable geometrical precision. These earthworks are believed to have been constructed by Native Americans associated with the Hopewell culture between A.D. 0 and A.D. 500. The limited archaeological evidence available suggests that these sites were neither habitation sites nor forts but probably had a ceremonial or religious significance. A recent survey of the Newark works and an analysis of an earlier survey of the High Bank works suggests that these earthworks may have been constructed in part to celebrate and record astronomical and geometric regularities. Specifically, the circle-octagon con-

figurations of both sites conform to simple yet precise geometrical plans based on a common length (321 m). Moreover, the shape and orientation of the structures may be understood as an attempt to record the extreme (north and south) rise and set points of the sun and moon. The resulting structures could have been used to provide reliable solar and lunar calendars.

Wattle and Daub in Mediëval Construction. GERALD SEELEY, Valparaiso University, Valparaiso, Indiana 46383, RUDOLPH STOECKEL, Florida Institute of Technology, Melbourne, Florida 32901, and FRANK SWENSON, Tri-State University, Angola, Indiana 46703.——The kings and battles theory of history has, perhaps, obscured the fact that the great majority of medieval folk did not live in *palazzi* or *chateaux*. When we imagine the past we rarely situate ourselves in humble cottages, but those infilled, beamed structures protected many generations of the European population in both towns and in monostic settings.

Wattle and daub buildings are more than an ancient construction technique: their presence provides a benchmark against which our developing culture measured what it considered its progress. Even the pre-Christian Vitruvius, interested in more impressive masonary structures, contemptuously remarks that "as for 'wattle and daub' I could wish that it had never been invented". The Renaissance, perhaps echoing the classical attitude, incorporates "wattle" into its arsenal of inventive:

> But he that is with such a humor led
> I may be bold to terme a watle-head
> (George Wither, *Abuses*, 1613, Satire I. 127)

One might even argue that wattle (if not daub) has a legitimate iconographic ancestry. The motif of wattle appears in medieval manuscripts (*The Belles Heures of Jean Duke of Berry* Fo. 71.v) and plays a crucial role in Renaissance portrayal of man in emergent technology.

As a construction technique wattle and daub offered a simple method to protect the medieval folk from the elements. It utilized local building materials (twigs, grass, and mud) and was inexpensive compared to the technique used in masonry construction. In order to assess the insulating characteristics a model wall was built and experiments were completed to obtain the heat transfer characteristics. The results indicate that wattle and daub has about the same insulating qualities as dried brick.

School Days

Paul Weatherwax[1] and Charles B. Heiser, Jr.
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Little Red Schoolhouse

It was not actually red at all, but a dull slate-grey. In other respects, however, it fitted very well the image of the one-room school building which dominated the system of elementary education in rural Indiana from early days down through the first quarter of the current century. Even today (mid-1967) a community in Monroe County mourns the passing of the last one-room school in the State.

My first contact with formal education came in the fall of 1896, when I was eight years old. We had moved to the farm north of Worthington in the spring of 1893. My older sister had had a few years of school, the latest being at old Point Commerce, near Worthington, where she was able to attend for a short time by staying with Grandfather and Grandmother Newsom. But for my younger sister and me there was nothing available within any reasonable walking distance. Such a thing as a school bus was unheard of in those days, and the winter condition of the mud roads would have made any such transportation impractical.

An important plank in the platform of a recently elected township trustee (Emory Haxton) was the promise to try to provide a school for our neighborbhood. The procedure for getting action was for those interested to present a formal petition to the trustee and his advisory board. My father carried the petition, and the response from those eligible to sign it was practically unanimous.

There was some controversy about where the building was to be located, but a site was finally agreed upon near the center of the area to be served. Being half a mile from any public highway, and reached only by way of a muddy lane, this location was not entirely satisfactory to anybody, but it was recognized as a practical compromise.

Construction was slow in getting started, and when the time came for the opening of school in early October, the building was not yet completed. So classes were conducted for the first week or two to the accompaniment of the finishing touches of carpentry.

Since this building was to be the focus of my educational activities for the next seven years, and I was later to teach for two years in similar surroundings, a brief description of the physical facilities is in order.

The building, a replica of a hundred others in southern Indiana, was of substantial frame construction about 24 to 30 feet wide and probably 48 feet long. The entrance, at the middle of one end, opened into what we called the "cloakroom." This served as a catch-all for winter coats, umbrellas, overshoes, water bucket, brooms, coal bucket,

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[1]The botanist Paul Weatherwax (1888-1976) was born in Indiana and long associated with Indiana University and the Indiana Academy of Science. The first two parts of his autobiography dealing with his early years and the old homestead were published in the Proc. Ind. Acad. 91:429-439. 1982. The present account covers the years from 1896 to 1918. Ecologists should find of particular interest the "environmental impact" studies being done in 1913.

fire shovel and tongs, and whatever else was considered inappropriate in the school room. The partition separating the cloakroom from the schoolroom proper extended only part-way to the ceiling, and two open doorways opened from the one room into the other. On cold winter days, when ventilation was reduced to the minimum, a never-to-be-forgotten mixture of odors of food and wet garments emanated from the cloakroom.

Lighting for the schoolroom came from six windows, three on the east side and three on the west. There were no window shades, but wooden shutters which could best be operated from the outside protected the windows. On bright sunny days we often found excuse for brief trips outside to open or close the shutters in conformity with the movement of the sun.

In the classroom the students faced north, and I have often had occasion to thank this arrangement for giving me a built-in sense of orientation in reading maps. The chalkboard, which was simply a section of the plastered wall painted black, extended across the front of the room and down to the first window on each side. With repeated use and many erasings, its surface took on a high polish which produced a troublesome glare when seen from certain angles. It could also give off a piercing shriek when the crayon was held at the proper angle, and we soon learned the trick of innocently injecting this diversion into the humdrum of daily activities.

During the winter months, heat was provided by a large coal-burning stove at the rear of the room, and in very cold weather some students were always too warm while others were too cold. Even those who were in the most favorable locations were usually too hot on one side and too cold on the other. Since the room was usually crowded, there was not much opportunity to move to a more comfortable seat. Moreover, it was generally understood that no one moved from his seat while classes were in session. There was no provision for artificial lighting on dark winter days, and the only air conditioning was accomplished by opening the windows.

The teacher's desk and chair on a rostrum about eight inches high at the front of the room gave a good view of what was going on in the room and provided a position of prestige sometimes much needed by a teacher scarcely older than some of the pupils.

Our library consisted at first of an unabridged dictionary, a four-volume set of encyclopedias, and a few other books brought from another school which had recently been closed. Each year a few volumes were supposed to be added from a list recommended by the State Department of Education. There was no other consistent plan for building up a library.

Drinking water was kept in a tin bucket in the cloakroom, and a single tin cup was the only facility for distribution. From the embryonic propaganda then current, we knew that this arrangement was not sanitary, but it was not until several years later that conditions were improved. A few of the more fastidious had their own private drinking cups, and some occasionally brought their own bottles of water, but most of us preferred not to go to that much trouble. Why did we not at least use paper cups? No one had ever heard of such things.

The water came from a spring at the foot of a hill some 300 yards away, and I do not recall that anyone ever questioned its purity. If it came from a spring, it simply had to be good. We had a tin wash pan and one towel, but water was too precious to be used for washing hands except in extreme emergencies.

The privilege of going to the spring for a bucket of water was usually reserved as a reward for good deportment or exceptional academic achievement. Some of us

cherished that privilege because it gave us an opportunity to wash our hands and drink all we wanted under better sanitary conditions. I recall that, although we drank from the full bucket and then emptied it and filled it again before taking it to the school, we sometimes had a guilty conscience and secretly discussed the ethics of such action; but we decided that it was no worse than for all to drink from the common cup.

There was a coal house for the winter fuel supply and an attached shed to shelter the horse when the teacher drove to school as some did. Rounding out the picture of the physical plant was the little outbuilding which served the purpose of the modern rest room. Since the economic situation provided only one of these, by tacit consent it was awarded to the girls. An adjacent patch of woodland with thick underbrush provided similar accommodations for the boys.

The curriculum, although I never heard of the word until many years later, was centered in a firm core of the three R's, with a fringe of peripheral subjects. Since the 25 or 30 pupils were often distributed among five or six, or as many as eight, grades, some ingenuity was required to fit all the recitations into the six-hour day. This was done by combining classes in some subjects, such as reading and spelling, by having two or three classes in arithmetic work problems simultaneously at the blackboard, and by alternating subjects on different days in the week. The daily programs were usually written on some out-of-the-way corner of the blackboard.

School convened, or "took-up," at 8:30 in the morning and "let out" at 4:00 in the afternoon, with an hour off at noon and a 15-minute recess near the middle of each half-day session. There was a strongly prevalent idea that subjects requiring much concentration, such as arithmetic and grammar, should be scheduled for the early hours of the day, when minds were supposed to be rested and active, and other subjects relegated to later hours. The day often closed with a free-for-all spelling match, in which all were engaged in one way or another.

The course in reading began with what we called the a-b-c's, that is, with recognition of the letters and learning to repeat them in alphabetical order. I do not recall that any teacher that we had placed any stress on repeating the alphabet backwards, an exercise which had been common in earlier days.

From "learning our letters" we went directly to the recognition of short, simple words illustrating basic phonic combinations and leading as soon as possible to reading simple sentences. We skipped completely the practice of earlier years when weary hours were spent on the sounds of meaningless combinations of letters. These early lessons in reading employed a Primer, a First Reader, and often a chart.

From the second year upward we used a graded series of readers, one for each year. These contained such classics as Grimm's fairy tales, Aesop's fables, Hans Christian Andersen's stories, and many others, often adapted to the age group for which the reader was intended. For the higher grades, sketches from the classics were used with little or no adaptation. These included poems of Longfellow, Whittier, Lowell, and others, selections from the Bible, great orations, scenes from Shakespeare, paragraphs from history, etc.

Although this was a few years later than the McGuffey era, much influence of the latter remained. Through all the readings there ran a strong thread of morality and patriotism and an emphasis on precise and beautiful expression. They left no room for doubt about what was right and what was wrong and pictured America and its institutions as the greatest and best on earth. The poetry, with its attention to rhyme, rhythm, and noble thought, engendered a love for beautiful expression which was to pay handsome dividends for our generation through the following years.

Good writing and oral expression were usually stressed. These accomplishments were as important in geography, history, or physiology as in the course in formal English.

Basic to writing, of course, was good penmanship. As an exercise conducive to clear, legible writing, we had regular sessions with a copybook. At the top of each page in this book was a sentence or series of words illustrating the movements necessary for mastering the various letter forms, and on the ten or a dozen lines below we copied these examples as well as we could. The teacher usually circulated around the room, watching for incorrect positions, wrong finger and arm movements, or other types of carelessness. At each exercise we wrote only three or four lines, the emphasis being on quality. Since the writing period often came just before recess, and the writing was done under the stress of anticipation of the playground activities, each line was often worse than the preceding one. This degradation where improvement was expected was further promoted by our tendency to copy the preceding line that we had written instead of the model at the top of the page. In spite of these shortcomings of the method, an examination of the copybook when it was finished showed improvement.

The style of penmanship used during my earlier school years was known as Spencerian. It was a clear, easily legible script, entirely devoid of the ornamental flourishes of some earlier styles. Unfortunately, the style was changed from time to time, and most of us ended up with a hybrid style sometimes lacking in both legibility and beauty.

Correct expression, oral or written, was taught by example and by reference to principles of grammar. We were told what was right and *why* it was right. The course in grammar defined the parts of speech and showed how words are fitted together to form sentences. A most useful technique for accomplishing the latter was sentence analysis, now almost a lost art as far as elementary education is concerned. We learned how to find the subject of a sentence and the verb which made it a sentence and then to hang the various modifiers around these essentials. If some part did not fit, we had to find out why and what to do about it. Years later, in a teachers' institute, I heard an educator thoroughly damn this method, his argument being that it was a destructive process when it should be a constructive one. As I listened, I meditated on how some of his grammatical crudities could have been polished out by a proficiency in sentence analysis. I have since learned also that one of the best ways of learning how to build a house or a machine or a dissertation is to take apart one that has been built by a genius.

Our systematic study of arithmetic began in about the third grade. Before that we had learned to recognize the figures and had dealt with some simple computations involving small numbers. Our first more serious approach to the subject consisted of exercises in reading and writing numbers, sometimes up into the decillions or farther. Then we took up in turn the various pocesses of addition, subtraction, multiplication, and division, staying with each until we could master numbers of any size.

In those exercises in subtraction in which it was necessary to "borrow" from the next column to the left, I discovered an interesting principle which has been the object of much meditation in later years. At school we were taught that when we "borrowed" from the next column at the left, we indicated the loan by decreasing by one the number from which we borrowed. At first, we were even permitted to indicate the loan by crossing out the one number and writing the smaller one above it. Later we were required to do the whole thing mentally. When we sought help on such problems at home, we encountered a different method. When something was borrowed, it had to be paid back, and the place to pay it back was in the proper column of the subtrahend. Any modern reader who fails to see what we are talking

about may see the difference between the two methods by examining two ways of subtracting 28 from 45. The new way can be shown thus: $\begin{array}{r} {}^{3}4\,{}^{1}5 \\ 2\ 8 \\ \hline 1\ 7 \end{array}$ But the old way is this: $\begin{array}{r} 4\,{}^{1}5 \\ {}^{3}2\ 8 \\ \hline 1\ 7 \end{array}$ Both methods gave the same correct result, but they operated on different principles, one mathematical and the other, shall we say, moral. Later, when place values had been explained, the better pupils were able to untangle the differences, but I am sure that there were many who never did understand what it was all about.

Multiplication and division bogged down for a year or two while we learned the multiplication tables. Here, again, some never completely made the grade.

Our next step was into the realm of common fractions, and we put them through the same paces—addition, subtraction, multiplication, and division—with hardly ever any explanation of why we did things as we did. I recall what an eye-opener it was when I discovered the meaning of the rule for division: "invert the divisor and then multiply."

Having disposed of common fractions, we were ready for decimal fractions, but why *decimal*? I remember that, as I listened to other classes reciting, one daring teacher introduced decimals away back with the reading and writing of numbers, explaining that this was simply a way of extending notation to the right of the decimal point. He went even farther to clear up the mystery of place values and to point out that we might have had some other system—the duodecimal, for example—if we had had some other number than ten fingers and toes. This was 50 or 60 years before anyone had ever heard of the "new mathematics" or of a computer.

Up to this point the numbers with which we dealt were largely abstract—merely numbers, not numbers of anything. For most pupils the studies were extremely boresome. But this was a conventional method of teaching, and woe to the pupil who expressed any dissatisfaction with it. The method had a counterpart in the teaching of music, where the learner spent endless hours in finger exercises before he was permitted to play even a simple tune.

Somewhere at about the fifth grade the numbers began to take on a more concrete form, and we met the percentage systems of computation, simple problems of business and banking, the tables of weights and measures and of the principal monetary systems, and simple problems based on geometry. Since the concrete problems encountered in these areas involved analysis and understanding, they presented a welcome series of puzzles for the better students and a baffling stumbling block for those with less imagination—sometimes even for the teacher.

I recall one teacher's frustration with this problem: How many square inches of tin would be required to make a quart cup 4 inches in diameter, no allowance being made for seams or for a handle? This teacher said the problem simply could not be solved unless we could find somewhere a quart cup 4 inches in diameter and measure its height. When one more resourceful pupil ventured to say that the problem could be solved with the information given, he was firmly "put in his place" because the teacher knew best. No one ever found a cup of proper dimensions, and for all but the one pupil the problem remained unsolved.

Geography, history, and human physiology were largely exercises in memorizing facts and spitting them back in recitations or on examinations. With a little time to think about it I can still name all the bones in the human body and the capitals of all the states and of all the more important nations in existence at that time and give

the dates of the administrations of all the presidents, but we were woefully short on insight into the relationships among all these facts. Although we were surrounded by woods and fields full of interesting and significant things, the best we could do with them was to pool our ignorance in making lists of birds, trees, and flowers on occasional Friday afternoons.

One of my regrets in later years, when I taught in a graded city school, was to see how much I had missed in having had no formal instruction in art or music. True, each day's program began with an "opening exercise" in which we often sang songs, but this could scarcely be dignified as an approach to music. In physiology we copied pictures from the textbook, and we sometimes made maps in geography and history. A few teachers scheduled periods in which we made drawings of leaves, flowers, animals, or other objects, but to other teachers, drawing pictures was little short of sinful. No matter how well a pupil had prepared his lessons, drawing pictures was a waste of time and a distraction.

Having one teacher who was especially prejudiced about this type of sin, we made the mistake of telling her that the teacher of the year before had had us draw maps in geography and history and we had found the exercise helpful and interesting. So, to teach us a lesson, we were told one afternoon to study the map of Europe carefully for 15 minutes. Then we were told to close our books and draw a map of Germany from memory. The result, of course, was a miserable failure, and that ended the matter of map drawing. On top of all this we were given a peculiar lesson in pedagogic morality: it would not be "fair" to draw a map with the book open before us; that would be "copying"—a kind of dishonesty.

In the seven years that I spent in the one-room country school we had seven different teachers. Rotation was the rule in those days, the theory being that it prevented the build-up of personal animosities and prejudices in the neighborhood. There was also a political angle to the arrangement. Some teachers were much more in demand than others, and some schools were much more desirable than others. The township trustee, who made the assignments, also had his problem, and he sometimes placed a teacher here or there with an eye to the distribution of votes. The other side of the coin—that what a teacher had learned in a year about the community and the individual pupils was good pedagogic capital which could well be put to use in subsequent years—was outweighed by the other considerations.

Since most of these seven have now gone to whatever reward there is for departed school teachers, it is probably safe to say that there were few real scholars among them. Some had graduated from high school, but none from college. A few had attended the State Normal school for a term or so. A high school diploma was not then necessary for admission.

Licenses to teach were granted almost wholly on the basis of a written one-day examination over the common school subjects, with a few questions on the most general principles of pedagogy. Grades in spelling and penmanship were based on the evidence of the paper as a whole. If the paper was graded in the office of the County Superintendent of Schools, the license could ordinarily be used only in that county. But, for a small fee, a dollar or so, the paper could be sent to the State Superintendent for grading, and the license was good anywhere in the State. There was a common opinion, probably sound in most cases, that the State office was a little tougher than the county, and less influenced by personal or political considerations.

A license might be granted for six months or a year, or longer for an experienced teacher, its duration being determined by the grades made on the examination. After the first year of teaching, a "success" grade, given by the County Superintendent on

the basis of a brief visit while school was in session—or often based wholly on hearsay—entered into the computation.

The examinations were such that a bright eighth-grade graduate could get a passing mark, and many did so. It was not uncommon for an intelligent youngster fifteen or sixteen years old to be teaching in a school where some of the boys were two or three years older and a foot taller.

For those who were afraid of the examinations or needed refresher courses for their advancement, there grew up a system of county normal schools, privately conducted by older teachers and lasting for a month or so in the summer. A summer institute, conducted officially by the county superintendent and lasting about a week, was designed for the same purpose and for orientation.

This kind of preparation for teaching in the grade schools—a reasonably good mastery of the common school subject matter, with a little attention to methods of teaching—was, in general, rather highly approved by teachers and school patrons. For many of them, high school dealt with useless frills. Who cared about the value of *x* or the conjugation of *amo*? So strong was this feeling that many who had finished the eighth grade and had no prospects of a job went back and took the eighth grade again.

This limited background of teachers sometimes led to interesting problems. Sharp disagreements often arose over matters of syntax or sentence analysis. Sometimes no one could manipulate certain problems in arithmetic so as to arrive at the answer given in the back of the book. One of the most daring things was to catch the teacher in a mistake or to ask what was the sense of studying such things.

Some typical reactions of teachers to such dilemmas provided a far better measure of competence that any of the other tests that they had passed. Someimes it was a violent explosion which put Johnny in his place without resolving the issue. At other times, it was a stern rebuke for him who dared to question the teacher's knowledge or the values of the system. Sometimes—often enough to keep hope and the spirit of honest inquiry alive—the teacher admitted the fault and humbly set about to try to find the truth about the matter. To this end, a visit with some older teacher often got results. Today a few minutes on the telephone would clear up such difficulties, but telephones did not arrive in our neighborhood until about 1904. As a final recourse, the monthly township teachers' institute served as a clearing house for many such difficulties.

In these teacher-pupil tests of wits, the bright pupil who had much time for idleness often had a certain advantage. He had seen the same problems threshed out, sometimes under direction of a more competent teacher, a time or two before as he had listened to recitations in classes a grade or two ahead of him in previous years. An occasional bright pupil who saw the principle clearly might not be averse to setting a trap for a bewildered teacher by innocently posing the trigger question in an apparently harmless form.

In spite of their limited general preparation for the teaching profession and these occasional specific shortcomings, these country school teachers at the turn of the century gave a pretty good account of themselves. As a rule, they were honest and conscientious, and they had a high sense of responsibility. They were usually good disciplinarians, if at times at bit harsh and arbitrary, and the discipline which they imposed not only maintained an orderly environment for learning processes but it engendered a sense of responsibility in the students. And in this capacity, the teacher usually had good support in the homes. The old rule, if you get a lickin' at school, you'll get another

one when you get home, was not always applied literally, but it always stood as an effective threat. I am not sure that the word *permissiveness* had even made its way into the dictionary at that time. I remember a few teachers who were criticised—some even being forced out of the profession—for being too lax, but none for being too strict.

In those days of no television, no radio, no movies, no PTA, and few if any telephones, the country school was the center of much neighborhood social activity. School patrons, teachers from other schools, and others with more tenuous connections frequently dropped in for afternoon visits. These guests were sometimes asked to speak to the school, and some did, occasionally much to the embarrassment of their own offspring and the teacher.

Before the Christmas vacation, and often in connection with other holidays, programs of music, declamations, dialogs, etc., were presented, and many patrons attended. A particularly significant meeting of this kind occurred each year on the last day of school. Preparation for this program began two or three weeks before the end of the term, and parents of the pupils and others who might be interested were invited. Classes were held as usual in the forenoon, and the special closing exercises were supposed to begin in the early afternoon, just after the noon recess. But shortly before noon the guests would begin to arrive with picnic baskets and other accoutrements of a neighborhood dinner. (Dinner always came at noon and supper in the evening; the word *lunch* was rarely heard.) Preparations for this dinner (always spoken of as a big dinner) were made more or less in secret, and the teacher was supposed to be suprised—and sometimes truly was—but more often than not, the news had leaked out in advance, and some skillful feigning of surprise was in order. After the dinner, the children's program was usually supplemented with speeches of approbation by leading school patrons and (often tearful) response by the teacher. A spelling or ciphering match was often added to complete the day's festivities.

The count of attendance and lavishness of the feast—especially the number of cakes brought in—were often noted as indications of community evaluation of the popularity of the teacher for that year. However, as I rate some of the teaches through the mists of threescore years, I find very little significant correlation between the magnitude of the celebration and the effectiveness of the pedagogic accomplishment.

Another enterprise making use of the country school facilities was the neighborhood literary society—more often known simply as the *literary*. I recall two or three short-lived endeavors of this kind at our school. The meetings were held on winter evenings, and the participants were mostly the younger adults of the community—some having no connection with the school. The group was organized with officers and committees, and a semblance of parlimentary procedure was observed, strange liberties sometimes being taken with the rules of order. Programs varied with the interests and talents represented—group singing, declamations, orations, debates, etc. Some of the debates were red-hot arguments about prohibition, woman suffrage, the relative evils of liquor and war, and current political happenings.

One interesting ingredient of the program was the neighborhood newspaper, in which innocent items of news were interspersed with sly personal jibes and veiled hints of scandal. I remember one newspaper of this kind which brought the literary to an abrupt termination for that season. A sporty high-flier of the community had overextended his credit to the point where his creditors closed in on him and took most of his chattels, including his horses. The literary newspaper told how its reporter had found our hero out back of the barn trying to work out some method of providing motive power for the family buggy by harnessing the turkey gobbler. The resulting

uproar brought the meeting to an end, and no attempt was made to revive the activity for that year.

Successful completion of the eight-year curriculum in the one-room school was marked by the passing of an examination set by the state board of education and conducted by the county superintendent of schools. This examination was the cause of considerable stress on the part of both the teacher and the eligible students. Success in passing it was a mark in favor of the teacher, and it admitted the student to high school. The test was usually given two or three times in the spring of each year, and if a passing grade was not made at the first attempt, the student had another chance or two. Some never did make the grade.

Four years after passing out of the eighth grade I had completed high school at Worthington and was ready to begin a career of teaching in a country school. This was in 1907. In fact, I had passed the county examination and received a one-year license a few months before finishing high school.

For my first year of teaching I was assigned to the McClarren school, in the north part of Jefferson Township, Greene County, a short distance south of the Oak Grove Methodist Church, which has since been destroyed.

My beginning salary was $42.00 per month, plus an additional day's pay if I attended the monthly all-day township teachers' institute. I secured board and room at the home of a relative about half a mile from the school. I think I paid about two or three dollars for five days each week, usually going home on week-ends.

I was reasonably well prepared in the subject matter to be taught, better, in fact than most teachers in such schools, many of whom had never seen the inside of a high school. But I was woefully deficient in methods of teaching and maintaining discipline. When confronted with problems in those areas, the best that I could do was to recall what my teachers had done under similar circumstances and plot my course in the light of their successes or failures. Such experiences, plus a little knowledge of psychology, are, of course, the very materials from which education methods are constructed, but I had had only a limited exposure to them. We muddled through fairly well, and I was later gratified to learn that the students had made reasonable progress during the year.

My second year of teaching was in a similar school at Point Commerce, the remnants of an old town on a hill above Worthington. My salary was a little better, probably something like $50.00 per month, and my year of experience enabled me to do a better job of teaching than I had done the first year.

One of my main regrets about that year was my failure to tap a rich source of information about the old town itself. Point Commerce had been founded in the early years of the nineteenth century on the hill above the junction of Eel and White rivers, a point from which flatboats started on their way toward New Orleans. It was also the head of steamboat navigation on White River—hence Point Commerce. Many older persons then living (1908-9) could remember the flatboat days and could have given me a wealth of first-hand interesting information if I had only had the foresight to take advantage of the opportunity.

The old one-room neighborhood school has been much maligned by some modern educators, but what would they have offered as a substitute? Consolidation to provide larger and better organized schools was simply out of the question. The roads were frequently hub-deep with mud in the winter, and the only conveyances available were slow, horse-drawn vehicles. Even if the roads had been better consolidated schools would have been impractical.

Students in those days usually received a good grounding in reading, writing, spelling, and the simpler aspects of grammar and arithmetic, with a fairly good introduction to geography and history. The rigid discipline bred a strong sense of responsibility and respect for authority. The days of "no lickin', no larnin'" were not yet a thing of the past, and a few teachers were still using that method of persuasion, but not so much to induce learning in the academic area as to maintain proper deportment. The later success of a reasonable proportion of those who took their first steps up the educational ladder there indicates that these schools were far from a total failure.

A concomitant value of the school was its unifying influence in the neighborhood. The school was a focus of interest in many ways besides being the center of the educational process, with a value which has been largely lost through extensive consolidations and long-distance transportation of school children for whatever purposes.

An unusually gifted teacher in those days might become an oracle of neighborhood information, answering difficult questions of fact, settling controversies, and especially solving mathematical problems. Those familiar with Whittier's *Snow Bound* may recall that one of the characters temporarily imprisoned in the farmhouse was the local school teacher, and it was rumored that his supreme accomplishment was his ability "to gauge," in other words, to determine the capacity of a container of specified dimensions. In Indiana this often meant finding the capacity of a wagon bed or corn crib in bushels of ear corn. The motive was often as much to catch the teacher off guard as to get an answer to the practical problem, and the teacher who could solve the problem usually commanded respect. If he had the presence of mind to ask whether the problem was to be answered in terms of the 27- or 28-inch gauge, his place in the community was made.

Another favorite problem to test a new teacher was to ask him to determine the number of acres in a triangular tract of certain dimensions. If it happened to be a right triangle and was recognized as such, many teachers could solve the problem without too much difficulty, but the formula for triangles in general was sure to stump all but the best.

The old country schools are gone, and some of the buildings still stand as empty ruins. Others have been demolished or converted to other uses, but nostalgic memories of them still linger with a few members of the older generation who spent some happy years in them. They were imperfect, of course, as most such institutions are, but they filled a definite need at a time when nothing better was possible.

First Steps in College and in Botany

My first contacts with college and with botany were, in some ways, taken by way of a side door. In those days all that was required for a teacher's license was a passing grade on a state examination, and many of us taught school for a year or so to get enough money to go to college instead of first going to college to qualify for teaching. My savings from my first year of teaching had been used for a surgical operation on my foot, and it was not until the end of a second year, in 1909, that I could consider college. While attending the county teachers' institute at Bloomfield in the summer of 1908 I had heard that Wabash College awarded a number of scholarships on the basis of a competitive examination, and in the fall of that year I went to Crawfordsville, took the examination, and received one of the scholarships.

At the end of my second year of teaching, in April of 1909, I enrolled at Wabash for the spring term. Since some of the courses, including botany, which I had no intention of taking, ran through the full year of three terms, they were not open to those entering in the spring. I had no difficulty, however, in arranging a program in English com-

position, history, trigonometry, and Latin. This was satisfactory because I was looking forward to becoming a teacher of high school Latin and mathematics.

The instruction in all these courses was good—except possibly in mathematics, where the aged professor spent many of the warm spring days in taking treatment for his rheumatism on the golf course—and I soon learned that the current idea that college was much more difficult than high school was largely a myth.

To occupy some of my spare time and make a little extra money I signed up with the Y.M.C.A. for odd jobs about town. It turned out that most of these were on the grounds of the old Lew Wallace home and in his library. I still have a vivid recollection of mopping the library floor, dusting the original manuscript of *The Fair God*, and untangling the fishing tackle once used by the distinguished author. I remember also a clash with the son Henry Wallace, who was directing the operation and who tried to tell me how to do my part of the work. It was a miracle that I was not fired.

Of course I could not know it then, but this work at the Wallace home was to impart a special enrichment to a contact some 35 years later with some of the Wallace memorabilia in the Palace of the Governors at Santa Fe, New Mexico. It also gave special meaning to the announcement about 1961 that the complete manuscript of *Ben Hur* had found a resting place in the Lilly rare book library at Indiana University.

In the summer of 1910, after teaching for a school year in the high school at Owensburg, I enrolled in a course in Latin and one in elementary Greek at DePauw University, still aiming at a career of teaching the classics. The instruction, given by assistants, was satisfactory but not exceptional, but I did have opportunity for a brief acquaintance with Professor Post, who was widely known as a teacher of Latin.

As a by-product of this sojourn in Greencastle I learned of a vacancy in the principalship of one of the city elementary schools. I applied for the position, but it was awarded to someone else. There was to be another chapter to this story.

I spent the short school year of 1910-1911 as principal of the school at Freedom and teacher of most of the high school offerings. In many ways this was the least satisfactory of all my experiences as a teacher. *Freedom* was a good name for the town, but *License* would have been better. In the school, and to a certain extent in the town, there was a spirit of rowdyism and little interest in orderly behavior and things intellectual, and the teachers received little support from the township trustee, who was too ignorant of school management to exercise the authority that he assumed, and whose son was one of the meanest boys in school. In justice to all it must be said that there were some good, well meaning students in the school and some substantial parents. The successful careers of some of the students in later years is a testimonial as to the personal qualities of some of the families rather than anything that the school did for the students.

The school year at Freedom was cut to six months because of a lack of funds, and in the middle of March I was free to consider what the future had to offer. I had no intention of returning to Freedom for another year even if invited, which was decidedly not indicated. Louis Johnson, a fellow teacher in the township, who had attended Indiana University for a term or two, and was planning to enroll for the spring term, suggested that I also enroll and that we room together. So I began my first term in the university in the spring of 1911.

My first impression of the university was good. It was still small—not yet 2,000 students—and so organized that any perceptive student could easily see where he stood. The relatively free system of selecting courses and planning programs appealed to the

mature, serious student. In later years I have heard some students and faculty members refer to it disparagingly as a "cafeteria system," but there is nothing wrong with a cafeteria if you know food values.

I selected a program of English, Latin, French, and mathematics—a total of 20 credit hours, which was five more than the normal load. My first problem was to convince a skeptical committee that I could handle the extra load, and my second was to crash the gate into a very special course in Latin. The entire atmosphere of the university appealed to me, and I had the feeling which, for some reason, I had never had at Wabash or DePauw, that I was getting somewhere.

My limited funds were exhausted by the end of the term in June, and, although the following summer term looked inviting, I saw no way of continuing. At home a month or so later I received a letter from Greencastle offering me the position for which I had applied a year earlier. I accepted, and, in view of this change of fortune, borrowed enough money to enable me to return to the university for the second half of the summer term.

The course offerings for this short session were limited, and some of them were "doubled" so that a five-hour course could be completed in half the ordinary time. I arranged for one such course—I think it was in English—and, knowing that I would sooner or later have to work in some of the sciences, I shut my eyes and enrolled in a course in botany.

From a theoretical standpoint, the circumstances under which I embarked on my first course in botany were most inauspicious. The elementary course at that time was organized on the basis of an evolutionary sequence; that is, it began with the algae and worked up through the main plant groups to the flowering plants. The part of the course in which I was now enrolled covered the liverworts, mosses, ferns, and gymnosperms. The first laboratory exercises dealt with *Marchantia* and some of the other liverworts, none of which I had ever seen, and it mentioned such abstruse entities as sporophyte and gametophyte. The mosses, which came next, were a little more tangible since I had seen them and had even wondered about the meaning of the little structures which I was now to designate as sporophytes; and as we proceeded toward the pine tree the concept of the alternation of generations, including the changes in chromosome numbers, began to make sense. As I recall, however, the word *meiosis* was never used, and I believe it was not mentioned in Mottier's laboratory manual. I was later to learn that, for some reason, probably based on some one of his ancient feuds with other biologists, he rarely, if ever, used the term *meiosis*, preferring to speak of it as the *reducing*, or *reduction, division*.

This awkward introduction to the science which was to occupy so much of my time and interest henceforth had one important redeeming feature; I had an excellent teacher. Henry F. A. Meier, who was later to serve for many years as professor of botany in Syracuse University, was a graduate student during the regular year and had been placed in charge of this short course during the summer session. Having spent several years as a teacher of biology in a high school in Evansville, he had developed good methods of presenting the subject, and he threw in many interesting points of ecological or anatomical significance around the main theme of a series of life histories. In spite of the strange new terminology and some startling new ideas, I found that much of the course consisted of an organization and refinement of some things that I already knew and the correction of some erroneous ideas that I had formed when observing things without the help of a competent teacher.

Another attractive feature of this first course in botany was the premium that it placed on drawing pictures, an exercise that had been discouraged, if not actually

forbidden, in my elementary school days and ignored in high school. I am referring not to art in the sense that a drawing expresses feeling and aims at beauty, but to the simple technique of drawing a picture to tell something a better way than it can be told in words.

One drawing which I made during this course, and which won high praise from Meier and was passed around and shown to other members of the botanical teaching staff, was a three-dimensional representation of a block of pine wood. The laboratory directions had called for separate drawings of transverse, radial, and tangential sections to show the main histological features, and I had put the three together in one drawing. That picture, with some additions and refinements, has since served as an illustration in at least three textbooks and has been imitated in others.

Whatever else may be said about this introductory course in botany, it changed my whole outlook on college goals and led to other courses in as rapid a succession as possible.

After teaching a school year at Greencastle I was back at the university for the summer session of 1912. As I rounded out the year of elementary botany, took a course in plant physiology, and filled in with a few courses from other areas, I saw the credits accumulating to the point where there was hope of graduation some day. I was also sold on the idea of changing my main objective to a career in botany.

Back at Greencastle that fall, I had hardly more than started the year of teaching when I received from Mottier a letter offering an attractive opportunity. The State Board of Health was planning a sanitary survey of the lower part of the White River Valley, to begin at Martinsville and continue to the mouth of the river, and they had invited Purdue and Indiana universities each to appoint one or two students to join the survey party and possibly to receive university credit for the summer's work. I was recommended for one of these appointments, but it was strongly suggested that I resign my teaching position and enroll in the university for the spring term (1913) to prepare myself to do some botanical work in connection with the survey. I was also offered a teaching assistantship for the following year (1913-14) with a stipend of $250.

The problem now was to secure a release at the middle of the year from my appointment at Greencastle. When I laid the proposition before the superintendent of schools, he was willing to release me if someone could be found to take my place. This was accomplished in a few days, and I was thus able to resign the positon without prejudice. However, when some of our neighbors and relatives heard that, to embark on what looked to them like a very nebulous prospect, I was giving up a position that paid $95 per month, they said they had always suspected that there was something wrong with my judgment and now they were sure of it.

Enrollment for the spring term was delayed for me by the flood of 1913, which blocked many railroads and prevented travel for several days. When I was finally able to get to Bloomington, I was agreeably surprised to find that many other students had had the same difficulty and enrollment had been delayed for a few days. So I was still on time.

The plan which we had formulated for the summer's work on the river was for me to make an extensive collection of flowering plants along the river and investigate the reestablishment of the algal flora which had been scoured out during the spring flood. To prepare for this I took a course on local flora and one on algae during the spring term.

I joined the survey party at Martinsville in June. A houseboat which had been

used on the Wabash River the preceding summer and had later been brought up White River, was to be our laboratory and living quarters for the summer.

Jay Craven and Jack Diggs, both from the State Board of Health, were in charge of the project, and one or the other of them was with us most of the summer. There were two appointees from Purdue, Estes Magoon and another man whose name I have forgotten. Magoon, a student of sanitary engineering, later spent many years in similar work with the Rockefeller Foundation in Latin America. I last saw him in Mexico City in 1956. State Water Chemist, H. E. Barnard, spent a few days with us, and his negro houseboy, Mentlow Ward was with us all summer as chief cook and bottle washer.

In those days, raw sewage from Indianapolis, Martinsville, Spencer, Washington, and a few other towns along the river found its way, often directly, into the river. Some work had already been done on the problem at Indianapolis, and our purpose was to make analyses for colon bacteria, chlorine, dissolved oxygen, nitrites, nitrates, etc. and the rates at which indicators of pollution disappeared downstream after receiving the effluent from each locality. We also made analyses of well waters in each town along the way. One result of the studies was an increased pressure on each locality, especially Indianapolis, to install adequate facilities for sewage disposal.

I would here urge ecologists—some of whom when reveling in an emotional jag, talk as if environment and pollution were concepts invented only yesterday—to note that such problems were recognized and being seriously investigated long ago.

We also had other problems incidental to our main work. Our houseboat was a clumsy craft, inadequately powered by a gasoline engine and rear paddlewheel. Several times we were temporarily grounded on sandbars or hooked on fallen trees in the stream. One snag punctured our hull so that repairs had to be made quickly to prevent sinking. We lived in bathing suits much of the time and never knew when we were going to be called on to jump into the river and help out in some emergency. Near Washington, where the Baltimore and Ohio railroad bridge had been washed out by the spring flood, we were held up for several days by a temporary bridge supported by piling so closely spaced that we could not get through. Finally, two wrecking cranes on the railroad picked our boat up and lifted it over the bridge. In spite of these difficulties, we had no serious accidents of any kind. Near Spencer we did aid in the recovery of the body of a local boy who had drowned while swimming.

There were many diversionary activities along the way—swimming parties, pitching horseshoes on sandbars, picnics with groups whom some of us knew in some of the towns, etc. Near Worthington I took some members of the group to see the famous sycamore tree, said to be the largest of its kind in the United States. This was just a few years before the tree was broken down in a storm.

Back at the university again in the fall of 1913 I spent some time in working over my collections made on the river expedition and then buckled down to work toward the bachelor's degree, which I completed at the end of the summer of 1914. I completed the requirements for a master's degree in 1915, and for the doctorate in 1918.

During my first year as assistant in botany, in 1913-14, I did mainly flunky work around the department—helping to take care of the library and greenhouse, collecting plant materials for class use, and occasionally helping out in a laboratory when the regular assistant could not be there. The following year I served as a regular laboratory assistant in elementary botany and had full charge of a small class in the summer session. At the beginning of the next year, 1915-16, I was appointed to the faculty as instructor in botany and had full charge of one small class in elementary botany.

One little interlude is worth mentioning. In the fall of 1914, I was asked to fill in for a month as teacher of Latin and history in the high school at Lyons. Because of differences in schedule I was able to do this without missing any time at the university, and the $105 that I received was a welcome windfall. As a by-product I made a number of new acquaintances and was later to meet children of some of these as students in the university. I recall what a pleasure it was 30 years later to meet on the backbone of the Andes in Ecuador a lady in missionary work who had been a student in the sixth or seventh grade at Lyons when I taught there.

The History and Development of Thermometric Titrimetry

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Introduction

Heat or enthalpy is a thermodynamic, and often easily measured, characteristic of all chemical reactions and has been used for many years for the estimation of such things as bond strengths, equilibrium constants and Born-Haber calculations. Only recently has significant advance been made in the precise measurement of minute temperature differences occurring in small volumes of solution, thus allowing for the measurement of enthalpies of reaction using micro-quantities of chemicals. This development was vitally important for the field of thermometric titrimetry because, almost immediately after the introduction of the thermistor as the temperature-sensing element, further new technology was developed and available to the scientific market, for example the transistor, which accelerated the evolution of the area to the precise, versatile and sophisticated field that it is today.

Initial Stages

A little less than a century ago, in 1886, C. B. Howard presented a paper before a meeting of the Finsbury Technical College Chemical Society in London concerning a simple method for the quality control of certain industrial chemicals, for example acetic anhydride. Unfortunately, apart from one reference to this (17), the society and its records seem to have been lost to posterity, although a number of attempts have been made to locate them. However, it is reasonable to assume that the apparatus used consisted of a thermometer and a Dewar flask. The method itself was likely to have been more akin to direct injection enthalpimetry (DIE) in its application *ie*: a known volume of acetic anhydride being placed into a Dewar flask and having a metered volume of water injected into it. If the temperature rise was over a certain predetermined value, the industrial product was considered to be of appropriate quality. It appears that the method was little used.

Twenty-five years later in 1909 an American, Henry Howard, published the results of his work on fuming sulfuric acid (13). He used the method for rapid assaying of industrial fuming sulfuric acid and had a somewhat more quantitative approach than did C. B. Howard. He used concentrated sulfuric acid as the reagent and made a few measurements of enthalpy of dilution which could, at best, be regarded as crude. Generally speaking, the method could still not be referred to as a genuine titration.

November of 1912 brought the submission of a paper to the Journal of the American Chemical Society (2), and it is regarded as the classic one on the topic. It was by James Bell and Charles Cowell and described what they referred to as 'the temperature method' for preparing neutral solutions of ammonium citrate. In this case a Dewar flask and buret were used, the former incorporated a mechanical stirrer, and the temperature differences after each addition of titrant were measured using a Beckmann thermometer. Quite clearly, with the publication of this paper, the method of thermometric titrimetry was born.

Instrumental Developments

a. *Vessel Design*

Various vessels have been used in which to conduct this type of analysis; for

example, Dewar flasks (3), metal cans (6), custom design flasks (12), and expanded polystyrene cups (8). In most cases, depending on how precise the determination is to be and whether or not the data are to be used thermodynamically, the vessel is surrounded by a thermostatted water jacket in order to decrease heat flow from the vessel. This heat flow has been eliminated in other ways, largely by careful design of the vessel (5). The solution of Christensen et al. was a specially designed and constructed thin-walled Dewar vessel, of perhaps 100 ml. capacity, which had a sconce machined from Teflon to eliminate further heat loss.

b. *Reagent Delivery Systems*

A number of devices have been used to deliver reagent into an analyte solution. Initially, a simple buret was used for the stepwise addition of reagent (7). This has been one of the preferred methods for many years, particularly for titrations on a fairly large scale; however, other methods have been used. For example, a simple pipet which was used for non-continuous delivery of titrant (10). This device, although simple to use, had the disadvantage of severely limiting the total volume of titrant deliverable, and so other more flexible devices had to be developed.

Ideally, continuous addition of titrant to analyte is the technique to consider and although Schlyter (19) partially solved this problem, there were inherent difficulties, again with reagent volumes. More sophisticated devices were constructed, in particular, ones in which the titrant could be kept at the same initial temperature as the sample solution (9). A far simpler arrangement using a syringe and a synchronous motor was devised by Linde et al. (15), and this allowed for simple temperature matching between titrant and analyte, rapid change of titrant and rapid filling of the titrant syringe. For most purposes, however, a slow delivery motor syringe is to be preferred (11, 14).

c. *Temperature Monitoring Systems*

Naturally enough, the first device for monitoring solution temperature was the mercury-in-glass thermometer (3, 17), but this was quickly exchanged for one of greater precision, the Beckmann thermometer (2). The latter, although capable of giving quite reproducible data, proved to be cumbersome and slow to use thus marking the way for a more sensitive device. The problem was solved, apparently fortuitously, by Linde, Rogers and Hume (15) when they became the first people to use an electronic temperature measuring device, the thermistor (4). Prior to this a number of other resistance devices had been used these being largely thermocouples and thermopiles (16). These devices had somewhat of a disadvantage in that they were slightly slow in response, and also their response was quite small. Most commonly thermistors are used in modern apparatus, having the advantages that they are very rapid in response and several orders of magnitude more sensitive than thermopiles (4).

d. *Recording and Measuring Systems*

Initially, the record of a thermometric titration was merely the transfer of a thermometer reading to a piece of graph paper (2, 7), but a number of quite ingenious devices have been used since then. For example, in 1941, Muller (16) replaced the Beckmann thermometer with a multijunction thermopile and used a differential thermoelectric experimental arrangement. The output, in this case, was on a mirror galvanometer, although a later modification was a recording millivoltmeter.

When Linde, Rogers and Hume introduced the termistor as a measuring device (15) they also incorporated a suitable measuring and recording circuit: this was the Wheatstone bridge. This apparatus is to be found in most modern equipment, and is the central component for many resistance-measuring devices. It may be powered

by both alternating and direct current sources but the latter is usually the case, and has a recording millivoltmeter attachment to measure the extent of bridge imbalance. For particularly small temperature changes, perhaps less than 0.001 °C, an amplifier may be inserted between the bridge and the recorder, provided that appropriate electronic filtering devices are used.

In some of the modern systems a deal of flexibility is made available by introducing a computer in place of the chart recorder (14). This has the advantage that it may be programmed to process the experimental information as it becomes available, so that the final hard-copy output has had all the necessary corrections applied to it and any detailed calculations performed for the determination of enthalpy, Gibbs free energy, entropy and so on.

e. *Commercial Apparatus*

Several pieces of apparatus are currently available but the first instrument marketed commercially was the "Titra-Thermo-Mat" (1) by the American Instrument Company. This device incorporated most of the modifications mentioned in previous sections: the titration vessel was a beaker embedded in styrofoam; the sensor was a thermistor with the associated Wheatstone bridge circuitry; recording was accomplished with a strip chart recorder. Also provision was made for stirring and variable volume titrant delivery. Many of these instruments were in use at universities and in industry, but there appears to be a dearth of accurate information as to precisely how many had been sold or were in use just before the apparatus was discontinued.

A more recent development, although designed for the specific task of determining silica, is the SILICOTHERM, appropriately named. It is an up-to-date modification of its predecessor the DIRECTHERMOM-"D" and contains a plastic reaction vessel fitted with a magnetic stirrer; otherwise the apparatus follows the design features of similar instruments with regard to titrant delivery, temperature sensing and recording. This device is manufactured in Hungary by Hungarian Scientific Instruments (20).

One final example of a commercial device is the Thermo-Titrator manufactured by Sanda Inc. of Philadelphia. This apparatus represents a slight departure from conventional apparatus in that it incorporates circuitry to provide a first derivative of the normal thermometric curve (18). The device is able to record conventional curves, "instant cut-off" curves and derivative curves with ease. The example shown in the paper quoted is the titration of phosphoric acid where all three protons are titrated.

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INFORMAL CONFERENCE

Issues in the History of Sciences
Moderator: GENE KRITSKY

ABSTRACTS

Sir Arthur Conan Doyle Indicted. CHARLES K. COOK, Tri-State University, Angola, Indiana 46703.——Did he do it? Was Sir Arthur Conan Doyle the perpetrator of the Piltdown hoax? A great man once said that "It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts." The man, of course, the only living 129 year old beekeeper in the South of England: Mr. Sherlock Holmes (1).

In their recent article (2) accusing Conan Doyle, Winslow and Meyer, though admitting the case against him to be "circumstantial, intricate, even convoluted" have provided means, motive and opportunity to substantiate the case against Conan Doyle. Unfortunately the only sources listed are (1) *Memories and Adventures* by Arthur Conan Doyle, in which psychic activities were only stressed in the second edition, updated in 1930, wihtin a few weeks of his death; and (2) *The Quest for Sherlock Holmes* by Owen Dudley Edwards, 1983, which covers only the first twenty-three years of Conan Doyle's life. A complete listing of Conan Doyle biographies can be found in reference (3).

Undeniably, and Sherlockian would admit that Conan Doyle possessed both the means and the opportunity, so the concentration here will be on motive.

First consider Conan Doyle's attitude concerning Spiritualism. In 1879 he wrote "When the body dissolves there is an end of matter." It took more than three decades to wear away Doyle's resistance on this point. So his total conversion to a fanatical spiritualist was very gradual. It wasn't completed until 1916 when he observed (and wrote later) (5) that he was lead "to understand that these psychic studies which [I] had so long pursued, could no longer be regarded as a mere hobby or a fascinating pursuit of a novel research." If he considered his earlier interests as a hobby, it seems unlikely that he would have invested thirty years to retaliate against Lankester over Slade. Doyle, himself, served as a special investigator (6) for the Society of Psychical Research and was well aware of the tricks used by spiritualist charlatans.

Next consider any vindictiveness that Winslow and Meyer claim that Conan Doyle held toward Lankester. Doyle was a busy man: writing prolifically, lecturing, traveling. It would seem unlikely that Lankester would be so important a target that Doyle would or could invest so much of his time and energy to so dubious a cause. But if he did and Lankester were the target, then Doyle misfired: Lankester could now be considered the motivating force behind the writing of *The Lost World*, which many consider to be Conan Doyle's finest work of fiction.

Furthermore, researching prehistsoric jungles and animals for *The Lost World*, Conan Doyle consulted Lankester, (7) a compliment to the eminent zoologist. Lankester's response went "you are perfectly splendid in your study of the 'lost world' . . . What about introducing a gigantic snake sixty feet long? Or a rabbit as big as an ox? Or a herd of pigmy elephants two feet high? Can four men escape by training a vegetarian pterodactyl to fly with them one at a time? Will some ape-woman fall in love with Challenger and murder the leaders of her tribe to save him?"

Is this an exchange between bitter enemies?

So much for the motive of vindictiveness. But could Conan Doyle still have been part of the hoax? (Perhaps participating with Dawson, as a practical joke, amusing at the time, but quickly forgotten?) It would seem reasonable that some reference be made in his writings concerning this event. The quote in *The Lost World* by Professor Summerlee suggesting that a bone could be faked is only a small clue. Conan Doyle probably would have referred to such a prank in a letter or a story in which the prank was the main theme. Unfortunately the Doyle archives have not been opened to the scrutiny of students and researchers (8). So all of the data may not yet be available. Hence, we must heed Holmes' admonition.

In conclusion, consider Conan Doyle, the man. It is known that he was honorable, and tenacious but fair. If he were involved in the Piltdown hoax, he would have left a major clue. To this end note that the scientific name of the purposely broken hinge on the skull is *condyle*, perhaps a signature and clue reminiscent of the blood written "RACHE" found on the wall in "A Study in Scarlet".(9).

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Issues in the History of Science—The Piltdown Hoax. GENE KRITSKY, Department of Biology, College of Mount St. Joseph, Mount St. Joseph, Ohio 45051.——The Piltdown Hoax is a complex chapter in the history of science. At first it was called the missing link, a fossil with both human and ape features, but later it was determined to be an elaborate fraud. Now three decades after the hoax was discovered, Piltdown still raises lively discussions about who was responsible and what was its significance. An informal conference during the History of Science division meeting examined the Piltdown hoax and the evidence implicating various participants.

Dr. Diane Beynon, Indiana University-Purdue University at Fort Wayne, reviewed the history of the Piltdown discoveries. Found in 1911 and revealed to the world by Charles Dawson in 1912, Piltdown man captured the attention of the British Museum's paleontologist Arthur Smith Woodward. Woodward tried to relate the fossils to the evolutionary tree of *Homo sapiens*. The anthropological world struggled with the fossils during the next four decades trying to fit them into the developing picture painted by the hominid fossils discovered in South Africa.

When the hoax was discovered in 1953, the issue became one of credibility. Anthropology was fooled by the bones, but it was also anthropology that proved they were indeed fake. Dr. Beynon argued that Piltdown was not a tragedy for anthropology,

but rather that it is evidence of its strength. The Piltdown episode shows how the science researched methodologies and reexamined previous finds. The Piltdown hoax has advanced anthropology with the development of sound field techniques that would make another hoax less likely in the future.

Dr. Charles Cook, Tri-State University, examined the new evidence that Sir Arthur Conan Doyle, the creator of Sherlock Holmes, may have devised the elaborate hoax in an effort to embarrass the scientific community. In a lively presentation, Dr. Cook presented evidence that Doyle did not want to set up the scientific establishment, but on the other hand, found a clue that Doyle would have left, if he were the perpetrator, namely a broken condyle.

MICROBIOLOGY AND MOLECULAR BIOLOGY

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ABSTRACTS

Perturbations in the Fecal Microflora of Red Squirrels Induced by Dietary Tannic Acid. T. DeNeff, K. Eberly, E. Mould, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Dietary tannic acid (0,0.5,1,2, and 5%) causes perturbations in the fecal flora of red squirrels whether diets are fed in random order or in order of increasing tannic acid concentration. The extent of that perturbation appears to be related to the *in vitro* tannic acid sensitivity of the microorganisms. Tannic acid containing diets were fed for a period of 7 days; fecal samples were aseptically homogenized with glass beads, diluted in saline, and plated on trypticase soy agar, eosin methylene blue agar, K F streptococcus agar, Saboraud's glucose agar, blood agar, and mannitol salt agar. Plates were incubated for 48 h. at 33 °C and counted; representative organisms were isolated and identified. Direct counts and gram stains were made from fecal samples to evaluate overall effects of tannic acid on the anaerobic fecal flora. Animals were returned to a control diet for 3 days, and then fed the next diet. Diets were fed in a random pattern.

Control of S-Adenosylmethionine Synthetase in *Mucor racemosus*. J. R. Garcia, Department of Biology, Ball State University, Muncie, Indiana 47306.——The specific activity of S-adenosylmethionine (SAM) Synthethase, was examined in cultures of the dimorphic fungus *Mucor racemosus* during the aerobic conversion of yeasts to hyphae. Previous studies showed that the intracellular concentration of SAM increased during the conversion and that the increase closely paralleled the emergence of germ tubes. The specific activity of SAM Synthetase also increased during the transition in cell type and began to decrease only after the intracellular concentration of SAM had peaked. Experiments with the morphological mutant *COY*, which requires high levels of methionine for the shift in cell type, indicated that the increase in specific activity (and the subsequent increase in SAM) may play a key role in morphogenesis. When *COY* was grown in the absence of methionine, a ten-fold decrease in the intracellular concentration of SAM occurred and the culture failed to produce hyphae. However, a twelve-fold increase in the specific activity of the synthetase was observed. If the mutant was grown in the presence of methionine there was a shift in morphology and an increase in the intracellular conc. of SAM. The specific activity of the synthetase increased and the magnitude was comparable to that seen in the wild type. In experiments with cycloleucine, an inhibitor of SAM Synthetase, the morphological transition was inhibited thus further strengthening the notion that the increase in specific activity (and in the intracellular concentration of SAM) is necessary for morphogenesis.

Pathways of Glucose and Fructose Catabolism by *Azospirillum brasilense* and *A. lipoferum*. Edwin M. Goebel, Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana, 46805 and Noel R. Krieg,

Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24060.——Members of the genus *Azospirillum* have been found to fix nitrogen in association with the roots of non-legume plants (e.g., corn, wheat, millet) in both tropical and temperate climates. It was known that the organisms were unable to grow with most disaccharides and polysaccharides, however the organisms grew well *in vitro* with simple sugars and organic acids. Previous results had also shown that *A. lipoferum* was able to use glucose as a sole source of carbon while *A. brasilense* was unable to grow with this monosaccharide. Our research was designed to answer two questions: Which pathways were used for the catabolism of glucose and fructose; and what factors allowed *A. lipoferum* to utilize glucose. The type strains of both species were cultured aerobically in a chemically defined medium with a fixed source of nitrogen. Cell extracts were prepared by passage through a French Pressure Cell and both soluble and membrane fractions were obtained by centrifugation. We assayed for the activities of the unique enzymes of the Embden-Meyerhoff-Parnas (EMP), Enther Doudoroff (ED) and Hexose Monophosphate (HMP) pathways, as well as the enzymes of the tricarboxylic acid (TCA) cycle. *A. lipoferum* was found to have a functioning EMP, ED and TCA pathways. It was found that *A. brasilense* contained all of the enzyme activities needed for the utilization of glucose, but was unable to take up radioactively labeled glucose. *A. lipoferum* was found to take up labeled glucose and both strains took up labeled fructose.

Local Antibody in Experimental Allergic Uveitis. CAROLYN M. KALSOW and CHERYL BARBATI, Department of Biology, Hope College, Holland, Michigan, 49423. Experimental allergic uveitis is an animal model developed to study the hypothesis that some human uveitides have an autoimmune etiology or component. Studies in the animal model have shown a lack of correlation of serum antibody levels to disease severity. In addition there has been a similar absence of correlation of antibody titers to disease in uveitis patients. In attempting to understand the immune mechanisms involved in this model disease, we have turned our attention to a study of local antibody in this model.

Using an enzyme linked immunosorbent assay (ELISA), antibody levels of serum and ocular tissues were measured in guinea pigs in EAU. These guinea pigs showed antibody activity to retinal extract in serum as well as in ocular tissues. The activity in serum was 2-6 times greater than that of the ocular tissues. Using a quantitative radial immunodiffusion system, levels of IgG were also measured in these sera and tissues. Again the levels in the serum were greater than those of the tissues. However, the ratio of antibody activity to IgG level was less in the serum than in the tissues.

These results indicate not only that antibody is present in ocular tissues during EAU, but that its presence there is not simply due to serum leakage into the inflamed tissue.

Effects of Anthracycline Compounds on Transmembrane Redox Function of Cultured Hela Cells

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Introduction

Anthracycline antibiotics are one of the most important agents used in the treatment of human cancer. It has long been thought that DNA is the primary target for the cytotoxic mechanism of this drug on susceptible cells (3,7,11,18). The DNA receptor hypothesis is attractive due to a reasonably high affinity between some of these drugs and nucleic acids. However, the N-substituted derivatives, such as N-acetyl daunomycin and N-trifluoro-acetyl adriamycin (AD 32), have very low affinity toward DNA, yet they are capable of inhibiting cell mitosis (6,7,11). Similarly, significant mitotic inhibition of daunomycin and adriamycin are observed under conditions in which DNA synthesis is unaffected (20,21). Therefore, there are reasons to suspect the anthracycline antitumor drugs might kill cancer cells in more than one way. Anthracycline antibiotics affect microsomal electron transport (1,2,19) and interact with the cytoskeleton (15). Studies of Goormaghtigh (9) have shown that adriamycin inactivates the last oxidation site of the respiratory chain, cytochrome oxidase. Furthermore, plasma membranes interact with adriamycin (12), and anthracycline drug-membrane interaction (8) and adriamycin effects on surface properties of sarcoma 180 ascites cells (14) have also been described. Recently, direct evidence that adriamycin can be actively cytotoxic without entering cells has been presented (22,23); the killing effect is achieved solely by action at the cell surface. To test this hypothesis of drug-plasma membrane interactions, we have, therefore, investigated redox enzymes, and pH changes, which can affect cell functions. From our studies, proton efflux coupled to the transmembrane redox system are observed. It is shown to be modified to a similar degree as redox functions by the action of anthracycline antibiotics. It is concluded that the plasma membrane is a promising target for these anticancer agents.

Materials and Methods

All chemicals were of the highest grade from commercial sources. Anthracycline compounds were obtained from Bristol Laboratories.

HeLa cells were grown in flasks with Eagle's medium containing 10% fetal calf serum, 100 μ u. of penicillin and 170 μg streptomycin per ml at pH 7.4 and maintained in a similar medium containing 2% fetal calf serum. Cells were prepared for study by pelleting the trypsinized suspension cultures at 27,000 g. The pellet was diluted with TD-Tris buffer (NaCl 8g/1, KCl 0.34g/1, Na_2HPO_4 0.1 g/1 and Trizma base 3g/1, pH 7.5) to a final concentration of 0.1 gm cells/ml.

The rate of ferricyanide reduction by HeLa cells was determined in an Aminco DW-2a dual beam spectrophotometer with a linear recorder, a cuvette stirrer, and a 37 °C temperature controlled cuvette chamber. The assay of ferricyanide reduction was performed as described previously (5), except TD-Tris buffer instead of 0.05 M sodium phosphate buffer, pH 7.0, was used. Absorbance changes were measured with the dual beam at 420 nm minus 500 nm. The extinction coefficient for ferricyanide reduction $\Delta A420$ equals 1 $mM \cdot cm^{-1}$.

Ferricyanide induced proton generation was measured in a 2 ml cuvette with an Orion 701 A pH meter and a Corning glass combination electrode. Cells were suspended

in a salt sucrose solution (10 mM KCl, 10mM NaCl, 10 mM $CaCl_2$, 0.1 M sucrose and 5% of TD-Tris buffer), to a final cell concentration of 0.005 gram wet weight per ml (g.w.w./ml). Sample was stirred continuously and air was bubbled through the reaction mixture to remove CO_2. After the pH came to an equilibrium, 0.15 mM ferricyanide was added. The proton generation was measured by the change in pH over the range from pH 7.0 to pH 7.4.

Treatment of cells with drugs was carried out using cells harvested during the exponential growth phase. The cells were suspended in TD-Tris buffer plus 2% fetal calf serum and incubated with various concentrations of drugs at 37°C for 1 hr. with shaking. After incubation the cells were chilled in an ice bath and diluted 10 fold with ice-cold TD-Tris buffer to stop the drug reaction. Surviving cell fraction was measurd immediately.

Cell survival was determined by using the eosin Y exclusion method after treating the cells with drugs. The colorless viable cells were counted. The method of using eosin Y as a vital stain for cells was described by Mishell and Shiigi previously (13).

Results

In order for internal NADH to reduce the impermeable ferricyanide outside the cell a redox system is needed to carry electrons across the membrane. The use of intact cells, therefore, provides an assay of the transmembrane redox enzyme activity. Figure 1 demonstrates two phase kinetics of ferricyanide reduction in HeLa cells (fast rate

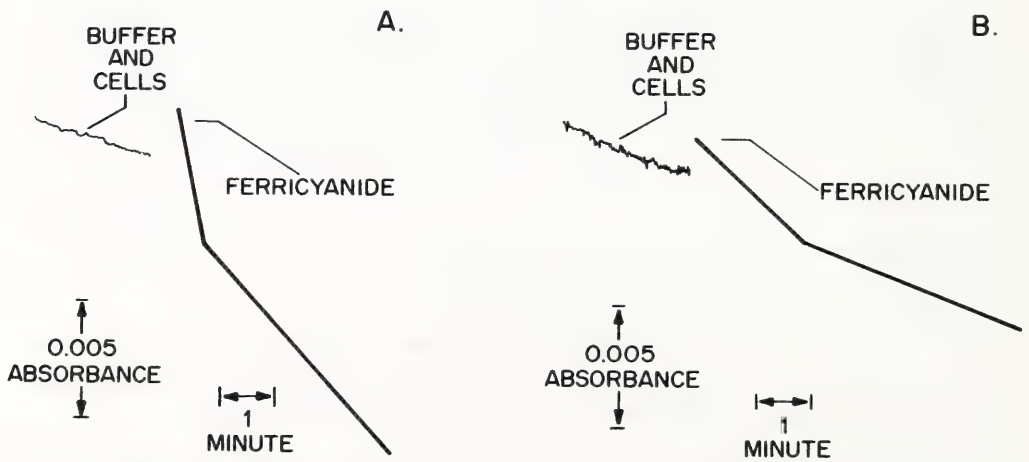

FIGURE 1. *Ferricyanide reduction by HeLa cells with and without the presence of adriamycin. A. without adriamycin. B. with adriamycin (10^{-6}M).*

and slow rate) with and without the presence of adriamycin. The rate of reduction increased in a sigmoidal manner with increasing ferricyanide concentrations (Sun and Crane unpublished). Reciprocal plots of the rate as a function of the ferricyanide concentration showed the aparent Km to be 0.125 mM for the fast rate and 0.24 mM for the slow rate (Figure 2). The maximum ferricyanide reducing activity up to .500 nmoles/min/g cells (wet weight) was observed for the fast rate. However, only about half of this value was reached for the slow rate.

The effect of adriamycin and other anthracyclines on the rate of HeLa cell ferricyanide reduction is shown in Figure 3. All anthracycline antibiotics give a significant inhibition of the fast rate at 10^{-7}M. A stronger maximum inhibition was seen with

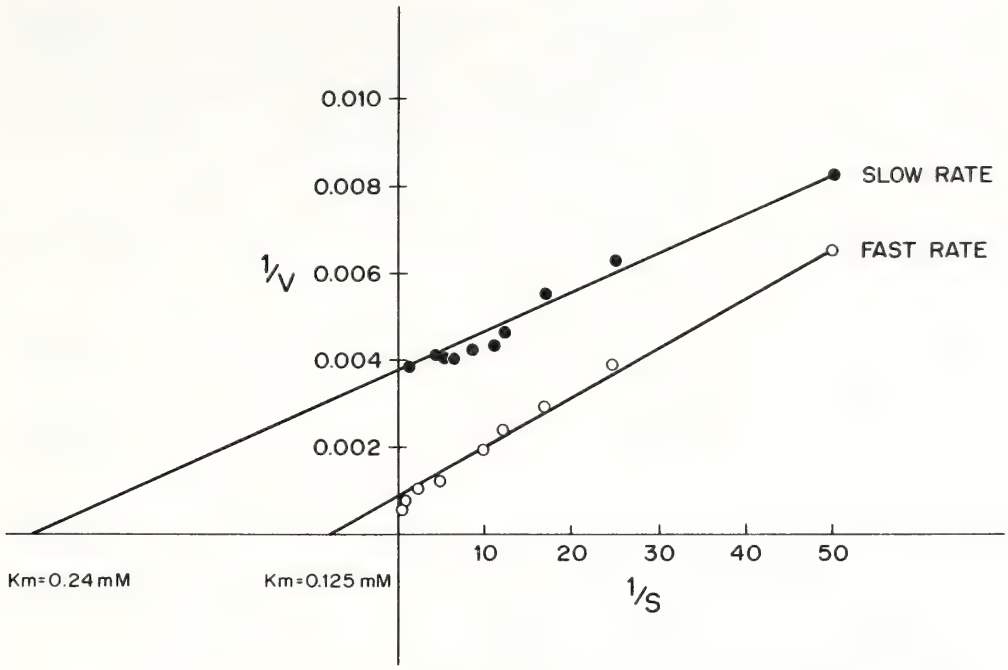

FIGURE 2. *Reciprocal plots of the rate of ferricyanide reduction as a function of ferricyanide concentration.*

adriamycin (90%) that with daunomycin and carminomycin (75%) at 10^{-5}M. Marcellomycin, aclacinomycin and even AD 32, which does not damage DNA, also caused 50% maximum inhibition at the same concentration. The slow rate of ferri-

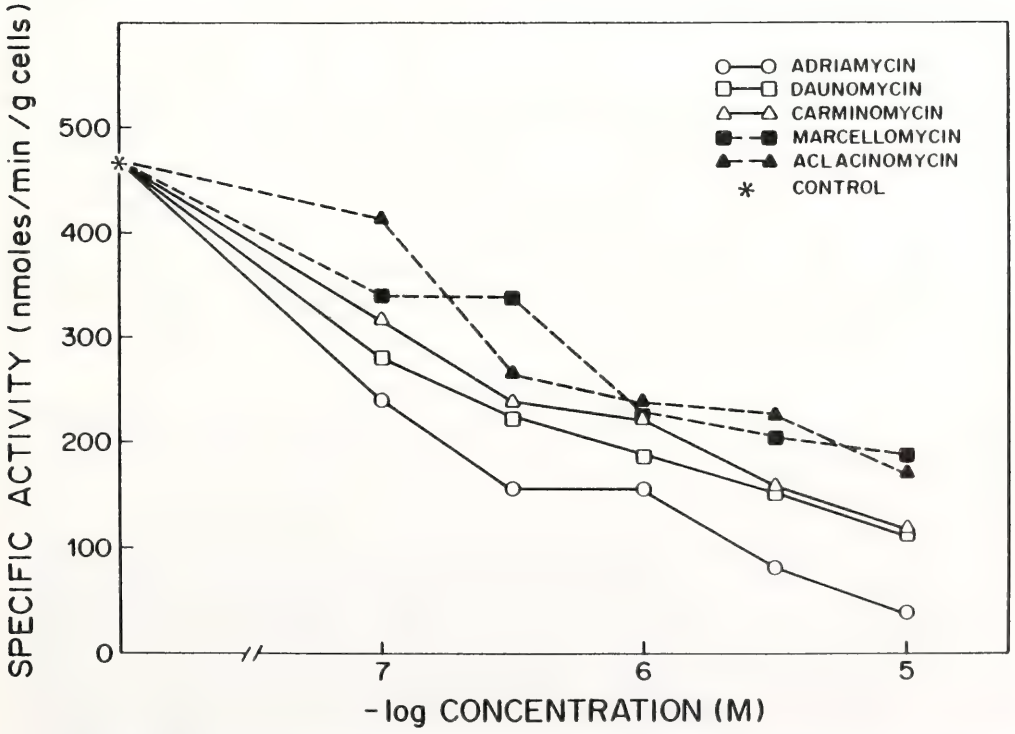

FIGURE 3. *The effect of anthracycline compounds on the fast rate of ferricyanide reduction in HeLa cells.*

TABLE 1. *The effect of anthracycline compounds on the slow rate of ferricyanide reduction in HeLa cells*

Additions	Slow rate without drugs (n moles/min/g.w.w)	Slow rate with drugs (n moles/min/g.w.w.)	% Inhibition
Adriamycin ($1X10^{-7}M$)	265	215	19
Adriamycin ($1X10^{-6}M$)	255	170	32
Aclacinomycin ($1X10^{-7}M$)	250	200	20
Aclacinomycin ($1X10^{-6}M$)	270	185	31
AD 32 ($1X10^{-7}M$)	260	195	25
AD 32 ($1X10^{-6}M$)	260	150	42

Drugs were added after the second phase rate was stabilized.

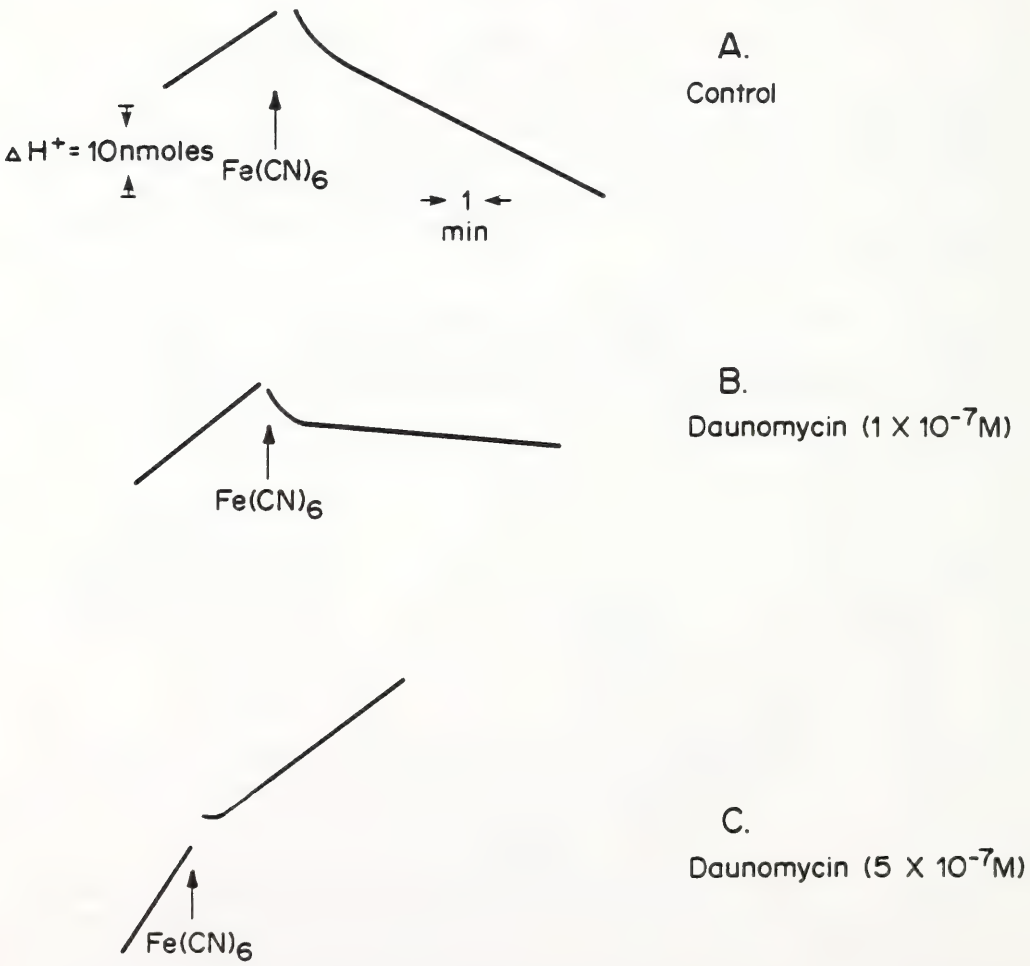

FIGURE 4. *The effect of daunomycin on ferricyanide induced proton release from HeLa cells. Cells were incubated in salt buffered solution at room temperature. The reaction mixture reached a steady rate of proton uptake within 5 minutes without ferricyanide. Addition of ferricyanide to the reaction mixture caused proton release from the cells. The rate of proton release was measured after the addition of ferricyanide and corrected by subtracting the blank rate in the absence of ferricyanide. The relation between pH change and proton increase was standardized by adding known amounts of 0.01M HCl.*

cyanide reduction was also inhibited significantly (31-44%) by the anthracycline antibiotics tested (Table 1). Actually, AD 32, which is the least potent in affecting nucleic acids, appeared to be the strongest cytotoxic drug among those three antibiogics tested in affecting the slow rate of ferricyanide reduction.

Coupling the proton release to the transmembrane redox activity was found in HeLa cells (Figure 4). Under the influence of these cytostatic drugs, a significant decrease (30-77%) in proton generation was demonstrated at a concentration range 1-5 x 10^{-7}M (Table 2).

TABLE 2. *The effect of anthracycline antibiotics on ferricyanide induced proton extrusion in HeLa cells*

Additions	Activity [n moles H^+/min/g cell (w.w)]	% Inhibition
Control	416	—
Adriamycin (1 x 10^{-7}M)	258	38
Adriamycin (5 x 10^{-7}M)	240	43
Daunomycin (1 x 10^{-7}M)	186	55
Daunomycin (5 x 10^{-7}M)	168	60
Carminomycin (1 x 10^{-7}M)	256	39
Carminocycin (5 x 10^{-7}M)	96	77
Marcellomycin (1 x 10^{-7}M)	256	48
Marcellomycin (5 x 10^{-7}M)	144	65
Aclacinomycin (1 x 10^{-7}M)	288	31
Aclacinomycin (5 x 10^{-7}M)	128	69
AD 32 (2.5 μg/ml)	297	30
AD 32 (5.0 μg/ml)	95	77

cell concentration was 0.1 g w.w/ml and $Fe(CN)_6$ was 0.3 mM.
w.w. = wet weight

The cytotoxic activities of anthracycline antibiotics were compared by measuring the surviving fractions of cells treated with various concentrations of drugs for 1 hr. Figure 5 shows the dose-response survival curve. A significantly large portion of cells were sensitive to the three anthracycline compounds tested at a concentration of 1 x 10^{-7}M. However, the curve indicates that cells were a little more resistant to AD 32 than to aclacinomycin and adriamycin. Similar results were previously (10) reported *in vitro* (human leukemia cells). AD 32 appeared to be 10 fold less potent than adriamycin as measured by effects on cell growth and cell survival.

Discussion

In this communication we propose that interaction of the plasma membrane with quinone anticancer drugs is important to their mode of antineoplastic action. The generally accepted mechanism of action for these antibiotics is based exclusively on their interaction with DNA and the inhibition of nucleic acid function (3,7,11,18). This interpretation has been questioned by us. According to the prevailing explanation intercalation of anthracycline compounds with DNA requires a free glycosidic amino group (17,25). In AD 32, the basic amino group has been converted into an amide. However, our results indicate that this compound still inhibits the growth of HeLa cells and induces effects on membranes. Similar results affecting the growth of cells (CCRF-CEM) in culture and producing a highly significant antitumor effect against mouse leukemia (10) by this drug have also been reported.

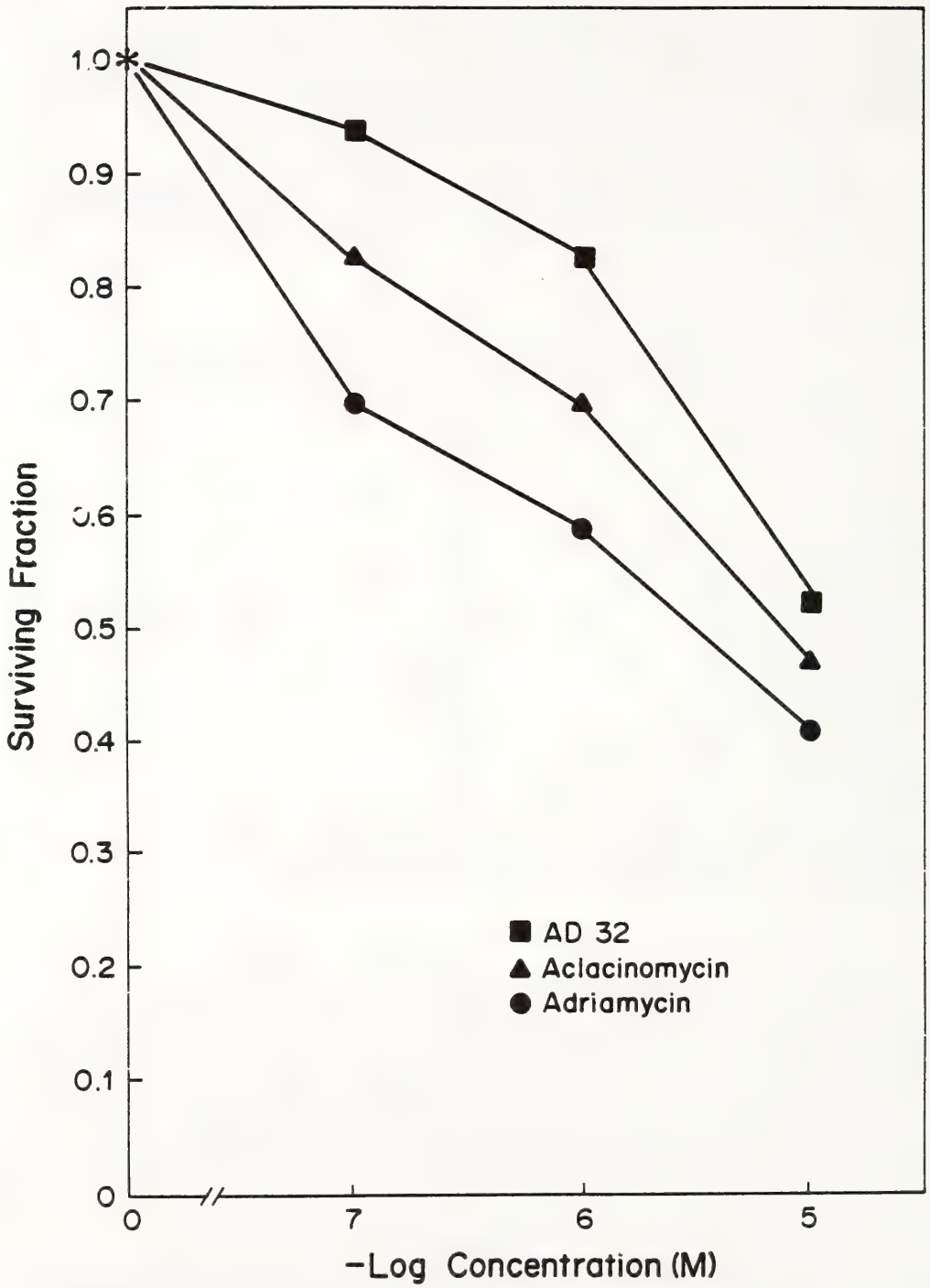

FIGURE 5. *The dose-response survival curve of HeLa cells after one hour drug treatment.*

The reduction of external ferricyanide by intact cells has been attributed to an NADH dehydrogenase which extends across the plasma membrane. Internal NADH is oxidized by external ferricyanide through this enzyme (4,5). The drug effect on ferricyanide reduction by intact cells indicates that the transmembrane dehydrogenase is inhibited. It has been proposed previously that the plasma membrane regulates cell functions (1). The effects of drugs on cell growth which we observe emphasizes that

this plasma membrane dehydrogenase is involved in the control of cell function. These enzymes have been related to selective amino acid transport (16). It is reasonable to assume that the inhibition of membrane redox enzyme activities could contribute to inhibition of cell function and cell damage caused by these drugs.

Tritton and Yee have directly demonstrated that adriamycin is able to destroy murine cancer cells (L1210) by acting on their plasma membranes (23). Adriamycin was chemically attached to insoluble agarose beads that are too large to get into cells. However, the cancer cells die. From a differnt approach, our results also provide direct evidence of drug and plasma membrane interactions as a cytotoxic mechanism for anthracycline antibiotics.

Although our analysis is carried out with a short exposure (3 min) of cells to drugs, the plasma membrane enzymatic and cell proton transfer parameters responded immediately. These changes can be regarded as a direct result of the effect of these antitumor substances. Evidence that the higher doses of drugs are accompanied by more morphological cell damage (granulation and formation of spherical instead of geometrical cells), as well as more pronounced changes in electrophysiological properties and plasma membrane redox activities further support this idea (Sun and Crane, unpublished).

The effects of cytostatic drugs on the surface charge of cultured cells has been reported (24). The results of this study clearly support the idea that redox enzymes and proton export respond rapidly in the plasma membrane and these effects are a sensitive indicator for effects on a great number of cell functions. It is also strongly suggested that it can be used as a parameter in pretherapeutic sensitivity tests for drugs.

Acknowledgment

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PHYSICS AND ASTRONOMY

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ABSTRACTS

Problems in Experimental Studies of the Zeeman Effect. Jolanta M. Czerwinski and Malcom E. Hults, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.——By studying the intensities of Zeeman components and hyperfine structure of forbidden lines, the presence of interference between electric-quadrupole and magnetic-dipole radiation can be determined. This effect can be obtained by observing the difference in relative intensities of the components in the Zeeman patterns when viewing parallel to the magnetic field as compared with viewing perpendicular to the magnetic field.

The purpose of this report is to illustrate how easily misleading are the data if the instruments are not properly checked and adjusted.

Laboratory Interfacing of the VIC-20 Computer through an A/D Converter. L. Dwight Farringer, Department of Physics, Manchester College, North Manchester, Indiana 46962.——Inexpensive home computers can provide low-cost laboratory computer interfacing experience for college science students. Hardward and software for doing this with the Commodore VIC-20 computer have been developed. For 8-bit digitizing of voltage measurement, an inexpensive ($5) ADC-0809 analog-to-digital converter has been used. With the use of an internal timer of the VIC-20, data logging can be done to record voltage data as a function of time over very short or very long time intervals.

The conversion time of the ADC-0809, operating at the VIC-20's clock frequency, is about 75 microseconds. By using a machine-language subroutine for rapidly storing data in memory locations and resetting the timer, voltage measurements can be recorded at intervals as small as 100 microseconds, so data points can be recorded at rates up to 10,000 per second. This method has been used for digitized recording and display of low-frequency sound waveforms. The stored data could then be used by a Fourier analysis program to compute the frequency spectrum of the waveform.

Laboratory Interfacing of the VIC-20 Computer through its Game-control Port. L. Dwight Farringer, Department of Physics, Manchester College, North Manchester, Indiana 46962.——Inexpensive home computers can provide low-cost laboratory computer interfacing experience for college science students. Hardware and software for doing this with the Commodore VIC-20 computer have been developed. At the simplest level, the control port intended for control of video games can be used. This port provides (a) five digital input/output lines which can be used for on-off signals, and (b) two inputs for variable resistances, from which the computer generates 8-bit digitized numbers proportional to the resistances. The computer also has internal timers which can be used for external time measurement.

Applications have been developed to use the digital I/O lines for such things as "stop watch" control of a millisecond timer, human reaction-time measurements, camera shutter-speed measurements, and photogate control of timing for measuring periods of pendulums or speeds on an air-track.

Applications have also been developed to use resistive transducers for measurement of such physical variables as motion, light intensity, and temperature. By use of timer subroutines, data logging can be done, e.g. measurement of temperature as a function of time, over very short or very long time intervals.

The Development of Computer Software for Use in the High School Chemistry and Physics Classrooms. ARTHUR MIDDLETON, Rensselaer High School, Rensselaer, Indiana 47978 and DAVID R. OBER, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.——A series of computer programs in Physics and Chemistry has been developed for the microcomputer. These programs deal with the analysis of laboratory data, quizzes, simulations, and autotutorials. Programs have been developed for both the classroom and the laboratory. The topics of the various programs will be presented and some sample programs will be illustrated. These programs will be discussed in the context of software that is commercially available at this time. A report on preliminary work involving the interfacing of microcomputers to laboratory hardware will also be given.

This project was supported in part by a 1983 summer grant that was awarded to Arthur Middleton and which was from the Indiana Academy of Science Secondary School Teacher Committee; the summer 1983 portion of the project was carried out at the Ball State University Department of Physics and Astronomy.

Photographing the Night Sky. ROGER L. SCOTT, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.——Many people, laymen and professionals alike, associate photography of the night sky with the use of telescopes and telephoto lenses. In fact, beautiful and educational celestial photography can be accomplished with an ordinary 35 mm camera mounted on a sturdy tripod. Using exposures of only 20 to 40 seconds, modern color film will record in vivid color all the stars that you can see as well as many others too faint for the unaided eye. The discussion will include simple techniques for night sky photography, as well as several examples of what can be accomplished.

Use of Mössbauer Spectroscopy to Study Indiana Oil Shales

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Introduction

Oil shales are recognized as being a potential source of petroleum for the immediate future. Indiana may have a source of valuable oil in its New Albany shale which is located in the southern and western regions of Indiana. Shales are sedimentary rocks formed in shallow seas which are mixtures of inorganic minerals and organic materials. The major organic constituent of the shales is kerogen which can be extracted from the rock and refined to produce petroleum products. Kerogen is a complex, acid-insoluble organic polymer which is formed from the decomposition of plants buried in the sediments. The process by which plant materials decompose and reform into kerogen as the sediments are compressed into shale is not well understood. In particular, the minerals in the shales which surround the organic material may or may not play a catalytic role in kerogen formation.

Investigations by the Indiana Geological Survey have shown that the New Albany shale has a number of characteristic rock formations which reflect the organic content of the shale. There is a black shale rich in organic material with a high potential for petroleum development, a greenish-gray shale which is poor in organic material, and brown shales with an organic content between those of the black shales and the green shales. Despite the obvious color differences in the shales, there are few mineralogical differences. For this reason, standard minerological techniques cannot be used in trying to determine the relationship of the minerals present in the shales to the formation of kerogen (Cliff, 1980 Lineback, 1970 and Shaffer and Chen, 1981).

It has been hypothesized that the organically rich oil shales were formed in an anoxic environment. The kerogen poor shales were formed in an environment high in oxygen which supported the presence of burrowing animals who ate the plants before the kerogen could be formed (Maynard, 1982). On this basis it is expected that minerals in the organic-rich shales will be in a reduced state related to those in organic-poor shales. This study reports an attempt to determine whether ^{57}Fe Mössbauer spectroscopy can be used to study differences in the mineralogy of Indiana oil shales.

Methods

Mössbauer spectroscopy is the resonant absorption and emission of gamma-rays. In order for a nucleus to resonantly absorb or emit high energy gamma radiation, it must recoil to conserve momentum. If the nucleus is found in a crystal lattice which can recoil as a whole to conserve momentum while taking very little energy from the gamma radiation, resonant absorption and emission can occur. The probability of this happening depends upon the energy of the gamma, the bonding of the nucleus in the lattice, and the temperature of the lattice. The most useful Mössbauer nuclide for the study of geological materials is ^{57}Fe because iron is abundant in all geological materials; the nuclide has a convenient low energy gamma transition at 1.4. KeV; and its parent nuclide ^{57}Co has a long half life and is convenient to handle.

When resonant absorption and emission of gamma radiation occur, the very narrow half widths of the nuclear transitions allow detection of the minute changes in the energies of nuclear levels brought about by the interaction of the atomic electrons

and the nuclear charge distribution. If the source nucleus and the absorbing nucleus are bound in different lattices, the energy levels of the source nucleus will not exactly match those of the absorbing nucleus. Energy is added to or subtracted from the gamma radiation from the point of view of the absorbing nucleus by moving the absorbing lattice relative to the source and using the Döppler shift to alter the energy of the emitted radiation. Transmission of radiation is measured as a function of the relative motion of the source and absorber.

Three parameters are measured from these absorption spectra which, coupled with the well-studied properties of the ^{57}Fe nucleus, present quantative information on the chemical state of iron in the absorber. The isomer shift of the center of the resonance spectrum measures the electron density at the site of the nucleus. Its value is characteristic of different iron-bearing minerals. The splitting of the nuclear levels due to the interaction of the nuclear quadrupole moment and the electric field gradient of the atomic electrons produces an absorption doublet whose splitting measures the assymetry of the electron charge distribution at the crystal sites where iron is bound. Finally, the interaction of the magnetic moment of the iron nucleus with the magnetic field produced by atomic electrons produces a six line absorption spectrum which is not observed in Mössbauer spectra of shales recorded at room temperatures.

Iron constitutes several percent by weight of the shales and they are therefore readily studied by Mössbauer spectroscopy. Karl and Zuckerman (1981) and Cole *et al* (1978) have used this technique to identify iron-bearing minerals in oil rich shales but have not studied shales with low organic content from the same formations.

In this study, four samples of New Albany shale with differing organic content were crushed and formed into absorbers whose thickness was approximately 50 mg/cm^2. Data were recorded on a conventional constant acceleration Mössbauer spectrometer using a gas-filled proportional counter and a nuclear data multichannel analyzer. The source in this study was ^{57}Co diffused into a palladium matrix to produce a source gamma with a single energy. Data were fitted using a version of the variable matrix minimization procedure developed at Argonne and modified at M.I.T., Columbia and Ball State. Constraints were placed on half widths of the absorption doublets and further doublets were added to the model spectrum until further doublets failed to reduce the chi squared value of the fit.

Results

Chemical data for four New Albany shales can be found in Table 1. The data were obtained from Nelson Shaffer of the Indiana Geological Survey. The shale sample NS79-9 is a shale rich in kerogen while sample NS79 308 is a shale poor in kerogen. The weight percent of the total carbon content in the organic-rich shale is much larger than that of the oil-poor shale. The weight percents of carbon found in the carbonate minerals of the shale also exhibit an obvious difference between the two shales. There

TABLE 1. *Chemcial Data on Shales*

Weight Percent of:	C	H	N	C in CO_2
NS79-9	24.15	2.19	1.20	.05
NS79-57	9.42	1.41	.35	.68
NS79-308	2.31	.53	.10	.74
NS79-309	8.56	1.15	.27	.12

is a lower percentage of carbon in the carbonate minerals in the organic-rich shale than in the organic-poor shale. The low percentage of carbon in the carbonate indicates that large amounts of organic material are present.

Figure 1 shows a typical Mössbauer spectrum. The absorption spectrum consists of two unresolved doublets. The narrow doublet is characteristic of ferric iron, while the wider doublet is characteristic of ferrous iron. The solid black line shows the computer fit used to distinguish between the doublets quantitatively.

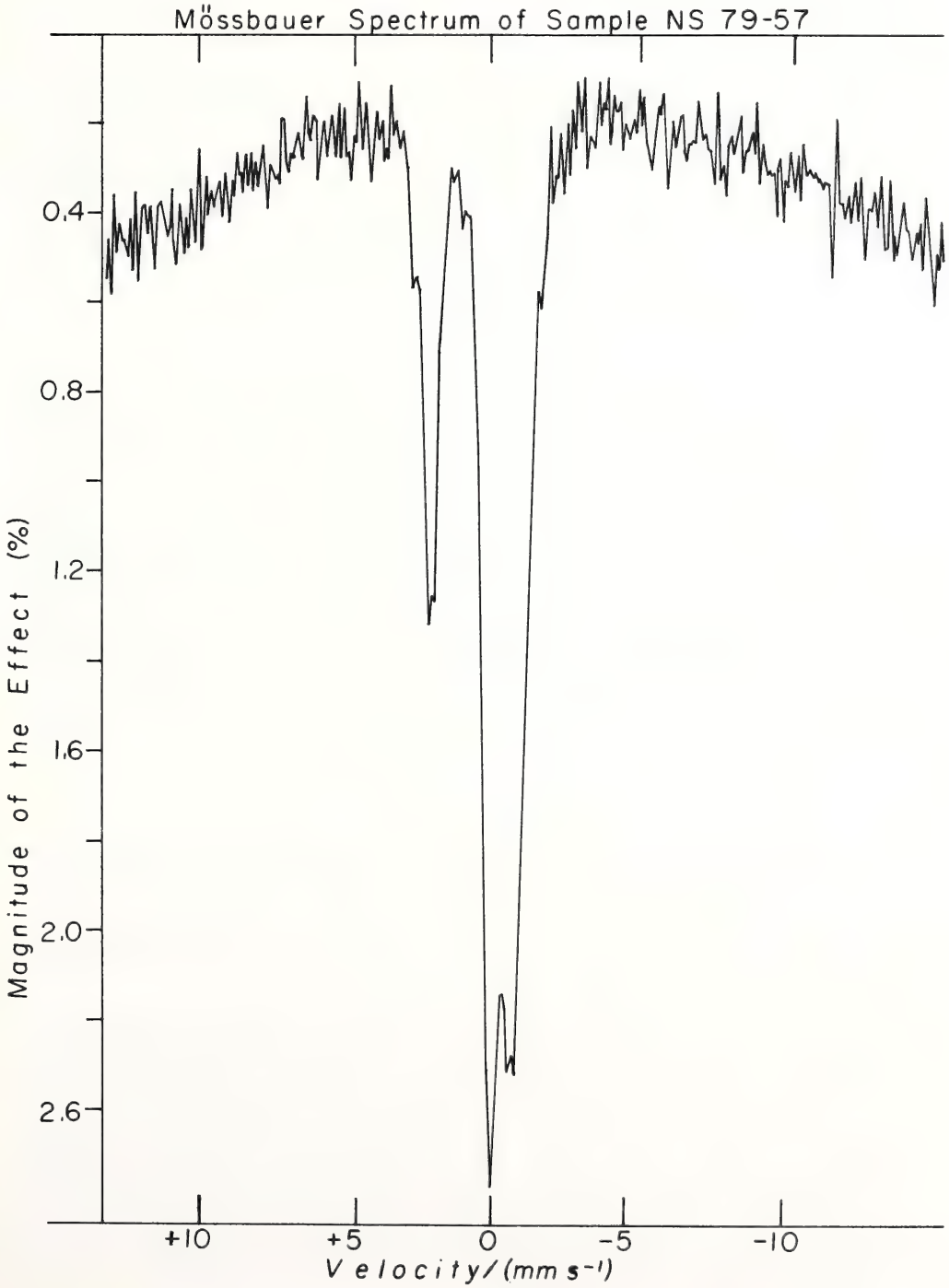

TABLE 2. *Mössbauer Parameters for Shales**

	Q_1	δ_1	%	Q_2	δ_2	%
NS79-9	.69	.30	68	2.81	1.14	23
NS79-57	.68	.31	70	1.89	1.23	30
NS79-308	.50	.43	25	2.56	1.12	74
NS79-309	.76	.32	63	1.95	1.52	29

* All quantities reported in mm/sec ± .10 mm/sec unless otherwise noted
Isomer shifts (δ) are reported relative to metallic iron

The results of Mössbauer spectra taken of the four shale samples are shown in Table 2. The first group of values indicate the data from the narrow doublet representing the oxidized (ferric) iron, and the second group indicates the data from the wider doublet representing the ferrous iron. The Q column is the doublet splitting. The δ column reports the isomer shift relative to metallic iron and the amounts of ferric or ferrous iron in the shale, assuming that the absorption cross-section is identical for all chemical sites in the shale and that the iron content is proportional to the area of its characteristic absorption doublet.

Conclusions

It was initially expected that there would be less oxidized iron than reduced iron in organic-rich shale samples such as NS79-9 and that the situation would be reversed in organic poor shales such as NS79-308. The results of this experiment contradict this simple hypothesis since experimental results show a higher percentage of oxidized iron in brown and black shales. Since this study involves only four samples, no general conclusion can be drawn concerning the mineralogy of the shales. The ferric doublet in the organic rich shales seems to be pyrite indicating, that for these samples, pyrite is associated with the presence of organic material in the shale. This is consistent with the chemical and mineralogical analyses of Levinthal and Hosterman (1982) and Maynard (1982). Further Mössbauer studies will yield detailed data on the relationship of the chemical state of iron in shales to the organic content of the shales. Such studies are currently in progress.

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Survey of Indiana High School Physics Teachers

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Introduction

The growing awareness of our country's crisis in math and science education has focused attention on the state of science and, particularly, physics education. A special concern is the increasing shortage of qualified physics teachers. As little data is readily available on exactly what is happening in physics classrooms, this survey was designed to collect data on high school physics classes in Indiana.

The Survey

The specific objectives of the survey were:

1. to assess the general conditions in the Indiana high school physics classroom
2. to gather data on the experience and needs of the physics teachers.

To encourage response, the survey was held to 20 questions on one page. This eliminated an in-depth study in any area, and the questions gathered only general data on class size, text, lab facilities, teacher educational background, *etc.* The survey is shown in Table I.

Table 1.

School Name _____ Enrollment _____
Address_____

1. Approximately what % of your graduates attend college or technical schools?____
2. Is physics currently offered at your high school? _____ yes _____ no
   If the answer is no, please answer the next two questions and return to Ball State.
   If yes, please answer questions 5-20 and return.
3. Physics was last offered _____ years ago. Physics was never offered _____
4. If it was offered, why was it dropped?
   _____ lack of student interest _____ lack of qualified teacher
   _____ lack of funds/equipment _____ other
5. How many semesters of physics are offered? _____
6. How many students are currently enrolled in physics? _____ How many are female? _____
7. Which of the following topics do you cover?
   ____ mechanics ____ E & M ____ optics ____ nuclear
   ____ thermodynamics ____ relativity ____ quantum mechanics ____ sound
8. What textbook is used? _____
9. How would you describe your lab facilities? ____ excellent ____ above average
   ____ average ____ inadequate ____ outdated ____ poor ____ nonexistent
10. What is your yearly budget for lab equipment and expendables other than paper?
    _____
11. How may semesters of math are a prerequisite for physics? _____
12. Does your high school offer computer classes? ____ yes ____ no
    How many semesters? _____

TABLE 1.—Continued

13. How many years of teaching experience do you have? _____
14. How many years experience teaching physics? _____
15. Indicate your highest college degree. _____
16. Indicate for your highest degree your major(maj) and minor(min)
    ____ physics ____ other science ____ math or computer science ____ other
17. If your major was not in physics, how many hours of physics do you have? (Total for all degrees held.) _____
18. Do you have a permanent teaching license ____ or are you working on one? ____
19. If you are working toward your permanent license and need to take physics classes, do you have problems finding them? ____ Where are you taking these classes? _____
20. Which of the following (you may check any number of them would help you the most?
    ____ night classes ____ summer classes ____ weekend workshops in physics
    ____ workshops on lab experiments ____ summer workshops in physics
    ____ workshops on repairing equipment other_____
    Any comments you would care to add:

A copy was sent to every public and private high school in the state, a total of 447 surveys. At this time 165 have been returned. At least one response was received from 71 of the 92 counties in the state. The southern third appears to be more sparsely represented than the upper two thirds but this may be due to the population distribution of the state.

Results

School enrollments varied from 100 to 4500 students: 46 responses were from schools with fewer than 500 students, 58 from schools with 501 to 1000 students, 46 from schools with 1001 to 2000 students, and 4 from schools with enrollments greater than 2000. Only two schools responded that they do not offer physics and they were dropped from the analyzed data. Sixteen of the remaining schools were private schools.

1. *Physics Classes*

One hundred thirty nine or 85.3% of the schools offer two semesters of physics. Twenty or 13.5% offer three or four semesters and one school offers six semesters. All schools with an enrollment of less than 500 offer only two semesters. Ten percent of all schools with enrollments between 500 and 1000 students offer three or more semesters and 33% of all larger schools offer three or more semesters of physics.

2. *Class Enrollment*

The total number of physics students represented by the survey was 5,023 with 1,491 (30%) girls. This projects a state total of 13,600 students enrolled in physics or 3.8% of all high school students. This is approximately 30 students per school.

3. *Topics Covered*

It appears that the average physics class is very traditional with a heavy emphasis on mechanics, optics, electricity, and magnetism, sound, and thermodynamics. It is disturbing to see that only half of the physics classes cover nuclear physics at all. With current heated discussions about nuclear power and weaponry, this is a vital topic. Lack of coverage is probably due to lack of time or inadequate materials.

4. *Text*

Texts in use are listed in the second table.

TABLE 2.—TEXTBOOK

Text	Authors	Publisher	Percentage
Modern Physics	Williams, Trinklein	Holt, Rinehart & Winston	49.0%
Physics Principles & Problems	Murphy, Smoot	Charles E. Merrill	15.0%
Physics Its Methods & Meanings	Taffel	Allyn & Bacon	9.2%
Physics	Giancoli	Prentice Hall	7.2%
Physics (PSSC)	Haber-Schaim, Cross, Dodge, Walter	Heath	5.2%
Project Physics	Rutherford	Holt, Rinehart & Winston	4.6%
Concepts of Physics	Miller, Dillon, Smith	Harcourt Brace Jovanovich	4.6%
Physics Fundamentals & Frontiers	Stollberg, Hill	Houghton Mifflin	2.0%
Physics	Genzer, Houser	Silver Burdett	2.0%
college texts			1.3%

Modern Physics is a traditional, well balanced text, suited for a basic college bound class. *Project Physics* and *PSSC* were NSF funded and very popular a few years ago but have recently lost favor. It should be noted that *Project Physics* is no longer on the Indiana textbook adoption list. Giancoli is a new text directed toward filling the gap between high school and college level texts. It is currently being used in several advanced classes. The college texts, by Halliday & Resnick and Sears & Zemansky, are also used in advanced classes.

5. *Lab Facilities*

Teachers were asked to rate their laboratory facilities on a five part scale from excellent to poor to nonexistent. Twenty eight percent of the teachers felt that their facilities were "inadequate, outdated or poor". On the other hand thirty five percent felt their facilities were "excellent or above average". Limited survey space precluded a detailed definition of an "ideal" high school lab so these data indicate teacher's perceptions of their own facilities and do not measure actual conditions in the high school labs.

6. *Budget*

With the current economic situation, supply and equipment budgets have been deeply cut. As physics is an area requiring occasional large expenditures for some equipment and where equipment is soon outdated, adequate lab equipment has always been a problem for high school teachers.

Twenty schools have no money available for equipment. This is 13% of all schools responding to this question. Nine schools responded that there was no budget, and they simply requested what they needed. Some indicated that they might or might not receive their requests; some indicated that approval was almost automatic. The average

supply and equipment budget is less than $400 per school year or approximately $11.66 per student per year.

7. *Math Requirements*

The average requirement is four semesters of math as a prerequisite to physics. Approximately one third of the schools require two semesters or less, and one third six semesters or more. Four percent (6 schools) have no requirements at all, although they appear to make some recommendation. This is obviously an attempt to encourage more students to take physics, but this may seriously affect the ability of the student to learn the more rigorous physics topics. It may also force the physics teacher to become a math teacher.

8. *Computers*

One hundred thirty nine schools responded that they do offer computer classes. All others intend to offer classes beginning this year. Eighty seven percent offer one or two semesters. Four teachers mentioned that they are incorporating computers into their class or are actively seeking to do so. There is a disturbing negative correlation between students taking computer classes and those taking physics which is significant beyond a .005 level ($r = -.2985$). Care must be taken that capable students are not faced with a choice of taking either a physics course or a computer class.

9. *Teacher Experience*

The average number of years of teaching experience for physics teachers was 16.7 with 13.5 of those years actually teaching physics. Ninety-one percent of the teachers hold a degree above a bachelors. Seventy-five or 46% listed physics as the major for their highest degree while another thirty-three or 22% have a minor in physics. This implies that at least 32% of responding teachers could not be certified to teach physics. Permanent licenses are held by 131 or 80% of the responding teachers. At least 12% of those with a permanent license could not be certified to teach physics. Of those without a major or minor in physics, the average number of semester hours of physics was 21.5. Seven of the responding physics teachers had no physics background at all and 10% had one year or less of college physics. The new graduation requirements will increase demand for teachers. As there are virtually no physics teachers in the education pipeline, it is clear that the problem of unqualified teachers will increase as tenured teachers from crowded areas are shifted into physics classrooms.

10. *Teacher Needs*

The last portion of the survey dealt with what the teachers felt they needed in and out of the classrooms. Their comments gave a strong indication of our system's failures and of their discontent. The comments fell into three categories; classroom assignments, money and personal education.

As physics classes comprise a small portion of the total student body, most physics teachers must teach several subjects, usually other lab sciences, creating a tremendous workload. For example they said: "I am currently teaching physical science, integrated science, PSSC and algebra. What kind of physics teacher could you guess that I am?" "Teaching five classes each day involving three different preparations and maintaining and setting up lab equipment is quite demanding—almost overwhelming."

As Indiana requires a masters degree for a life license, physics teachers find themselves in a position that is particularly unattractive. Their technical skills would be better compensated elsewhere; they must give up summer or night employment to take classes and they must pay for a required education which many industries provide for employees. They said: "Engineers are currently starting at $25,000. I have topped

out at less than $19,000 with 20+ years and MS. There is your problem and you know it." "Money problems make summer programs impossible. Few of us can afford to pay the prices asked to go back to school."

Continuing their education poses a problem for the scattered handful of teachers than can obtain their masters. Universities offer courses directed toward the physics MS and PhD candidate which contain little information that a high school physics teacher can directly utilize in his classroom. Education courses tend to slight physics content. A mixture seems to be unavailable. Teachers said: "I find it very difficult to take courses in physics. They just aren't available!" "Teacher education in the sciences is the pits. Virtually no one teaches how to teach and finding physics courses at a graduate level that are not aimed at PhD candidates is an exercise in frustration!"

The teachers surveyed stated a need for classes directed toward lab related work such as developing new labs, incorporation of computers in labs, learning to repair equipment and sharing experiences with other teachers.

Recommendations

There are many suggestions for improving the physics teacher's condition. Only a few of them are mentioned below and they are classified in two broad categories. Concerns for the state legislators and school boards include:

1. Higher teacher salaries and supply budgets to counteract drain of teachers into industry.
2. Teaching loads requiring fewer preparations since most physics teachers are simultaneously teaching several subjects.
3. Special consideration needs to be given to teachers of laboratory courses either in the form of reduced extracurricular duties or of extra monetary compensation.
4. The state needs to consider revising its requirements for a permanent teaching license or perhaps eliminating the lifelong license.

The Universities need to do the following:

1. Offer more short term courses and workshops especially for teachers.
2. Develop advanced courses and degrees designed for teachers of high school physics.
3. Revise degree programs for teachers to encourage more students to become physics teachers.
4. Upgrade admissions standards to increase enrollment in high school physics.

Conclusions

In general, conditions in Indiana high school physics classrooms warrant immediate concern.

1. The lab facilities in our schools appear to be adequate but cannot remain so for long with small or nonexistent budgets.
2. Even if adequate texts and labs are available, 10% of the teachers are totally unprepared to utilize them. Another 22% may not be certified.
3. As high technology increasingly pervades our society, we will need more and more citizens who understand basic physics yet we do not have teachers to meet current demands for high school physics classes.

4. Physics teachers have few incentives to keep them in the classroom other than a dedication to their profession, lack of other employment, or a three month summer vacation.
5. Due to the small number of physics teachers, relevant advanced classes in physics ar hard to find.

The results of this survey present a grim picture of conditions in Indiana high school physics classrooms which can only grow worse unless conditions are changed quickly. We fear that this survey, if anything, presents too rosey a picture of conditions throughout the state. Many of our surveys were not returned, and although some were undoubtedly lost due to teachers' heavy work loads and reluctance to fill out surveys, many missing surveys represent schools which lack well-qualified physics teachers. Certainly this seems to be the case in those few schools where we can check survey results by independent means.

In our increasingly complex technological society, we will need many more high school graduates who understand physics. We must therefore make every effort to design more high school physics courses at varying levels of difficulty and to actively recruit students to take them, perhaps by raising high school and college science requirements. We must increase equipment budgets, decrease the workload of the physics teacher, recognize his/her technical value with monetary or other rewards and design advanced courses for her/his specific needs. To do these things will require the cooperative efforts of the schools and universities, the community, industry and local, state and national governments. Only then can we hope to bring the excitement of physics to more students and to provide Indiana with the technically literate citizens she will need to face the challenges of the twenty first century.

The authors wish to thank Dr. Thomas M. Harris of the Ball State University Computer Center for his help with analysis of these data. We would like to acknowledge the effort of those dedicated teachers who promptly returned their surveys and thank them for their many comments.

PLANT TAXONOMY

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ABSTRACTS

The Portable Microcomputer and Herbarium Research: Distribution of Indiana Red and Black Oaks. Richard J. Jensen, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Plant distribution records are based on voucher specimens deposited in herbaria. Deam presented distribution maps and the location of voucher specimens for all taxa included in his *Flora of Indiana* (1940). Since that publication, there has been no revision of the distributions of many taxa, including the red and black oaks. During the summer of 1983, I used an Osborne-1 portable microcomputer, employing a data storage and retrieval program, to establish a file of voucher specimens for each of nine red and black oaks, including hybrids, occurring naturally in Indiana. The data file was constructed from specimens examined at the following herbaria: Ball State University, Butler University, DePauw University, Earlham College, Field Museum, Indiana University, Miami University, Purdue University, Saint Mary's College, University of Illinois, University of Notre Dame, Wabash College. When the data gathered are compared to Deam's (1940) records, it is found that (1) some of Deam's reports cannot be verified, (2) there have been a number of additional county records since 1940, (3) some of Deam's reports were based on misidentified specimens, and (4) several hybrid combinations should be added to those mentioned by Deam.

A Biosystematic Study of Selected Members of the Genus Crataegus Employing Electrophoretic Techniques. Mary Ann Morse, Indiana University East, Richmond, Indiana 47374 and Betty D. Allamong, Ball State University, Muncie, Indiana 47306.——Polyacrylamide gel electrophoresis was employed in an investigation of peroxidase isozymes extracted from the mature fruits of seventeen individuals belonging to the genus *Crataegus*. The purpose of this study was to develop procedures which could supplement existing information contributing to the biosystematics of this genus.

Samples were detected on 5%-20% linear gradient gels in a sodium borate—boric acid buffer (pH, 9.0). Following electrophoresis, incubation was carried out in a solution containing benzidine dihydrochloride and hydrogen peroxide in an acetate buffer (pH, 4.5).

Resulting zymograms were analyzed and eight different isozyme bands identified, based on width, staining characteristics and relationship to a horseradish peroxidase standard zymogram. Composite zymograms were drawn for each species, based on frequency of occurrence of individual bands. Within each species, some isozymes were observed in 100% of the individuals, while other bands appeared in 20% to 92% of the gels examined. Three of the seven species investigated exhibited unique zymograms. Similarities were noted in isozyme patterns among species. Three groups of species were established based on the presence or absence of certain variable bands. Two of these groups had some correspondence to series groupings based on observable

morphological characteristics. A third group consisted of species not related in traditional classification.

Natural Barrens and Post Oak Flatwoods in Posey and Spencer Counties, Indiana

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Introduction

Post oak flatwoods are xeric forested communities that are dominated by *Quercus stellata* with a relatively open canopy that allows a great deal of dispersed light to reach the forest floor. This forested community lacks the typical shrub-layer found in more mesic forested communities and appears "savanna-like". Characteristically, post oak flatwoods in Indiana are found on poorly drained nearly level soils of alluvial lacustrine terraces of the Ohio River and other major streams in the unglaciated region of the Wabash Lowland Physiographic Province (12). The understory is dominated by sedges and the content of organic matter in the soil appears to be very low. The barrens described herein are relatively small natural openings surrounded by post oak flatwoods where a fragipan is at or very near the surface. The vegetation in these barrens is not dominated by prairie grasses and forbs, but is closely related to the vegetation of sandstone glades described for Illinois (21) and Missouri (18).

Contemporary southern "flatwoods" of the Illinois Tillplain dominated by sweetgum (*Liquidambar styraciflua*), beech (*Fagus grandifolia*) and red maple (*Acer rubrum*) in southwestern Ohio (4) and southeastern Indiana have been described in detail (9,13,15,17). Indiana "barrens" dominated by prairie forbs and grasses (7) have been discovered recently and discussed (3,10). Flatwoods dominated by post oak have received limited attention in Illinois (16) where they have been referred to as "southern flatwoods" (21) and very little has been written about the Indiana post oak flatwoods. The barrens associated with post oak flatwoods have not been previously described for Indiana (8) or to our knowledge, elsewhere. The best remaining examples of these types of natural communities in Indiana are of state, and possibly regional, significance and have an interesting flora that includes many species that are considered rare, threatened or endangered (1,2). A species list is presented for the post oak flatwoods and barrens communities with some additional information regarding some very rare floristic elements, including two native vascular plant species, *Isoetes melanopoda* and *Trichostema setaceum*, that are new to the Indiana flora.

Methods

A systematic search for post oak flatwoods and associated barrens of high natural quality was made in Spencer and Posey Counties from April to October, 1983. Some preliminary field work was conducted from 1980 to 1982. Initially, aerial photo base maps for Spencer (22) and Posey (14) Counties were examined in conjunction with 7.5′ United States Geological Survey topographic quadrangle maps and 1940 aerial photos to identify potential post oak flatwoods and barrens. These areas were then flown in a helicopter at an altitude of 300 to 1000 feet, and the potential sites were examined to determine the presence of barrens and/or extensive stands of post oak, as well as obvious signs of disturbance.

Subsequently, sites were field checked to evaluate their natural quality. Those that were determined to have high enough natural quality to warrant preservation efforts were visited every six to eight weeks to compile vascular plant species lists. Common and easily identified species were recorded but not collected, whereas species that are

rare in Indiana or that were difficult to identify were collected to document their occurrence. Voucher specimens of these will be deposited in the Deam Herbarium of Indiana University—Bloomington. The nomenclature follows Gleason and Cronquist (5) except where noted otherwise.

Plant Communities

With some exceptions, Spencer County consisted mostly of dry to dry mesic upland forest before it was settled by European man (6). In the Bloomfield (Grass)-Chrisney-Gentryville areas near Little Pigeon Creek shrubby black-jack oak thickets and small brushy barrens were present (19). In the early 1800's, land surveyors made many references to "barrens" and "flats" in sections within T6S R6W. Some noteworthy examples include: "briery, brushy flats with black-jack oak" in section 1, "hazel thickets-no timber" between sections 12 and 13, and one-half of the area traversed between sections 10 and 11 and sections 1 and 2 were described as "barrens" or "brushy barrens". Also in section 24 T5S R6W a surveyor noted, "briery, brushy, barrens" and "¼ post . . . in burnt land-no live timber for bearings." In sections thirty-two and thirty-three, which includes our study areas, no mention of post oak was made by the surveyors. Either they referred to it as "scrub-oak" or mistook it for some other species.

Some of this area became Classified Forest Land in the late 1920's and was visited by Indiana botanist Charles C. Deam, the State Forester at the time. From plant collection labael data on herbarium sheets it is possible to discern that many early well known Indiana botanists visited the flats north of Grass. In 1929, Deam first collected rush-foil (*Crotonopsis elliptica*—84428 IND) in a "low flat post oak—pin oak woods" and Ray C. Friesner (s.n. BUT) and John Potzger (240472 ND) collected the same species here on September 3, 1937. Deam revisited the area on September 4, 1939, collected *Hypericum denticulatum* (81515 IND), and apparently was accompanied by Ralph Kriebel (*C. elliptica* 12255 PUL), Scott McCoy (*C. elliptica*) and Rolland and P. Tryon (*C. elliptica* 54052 DPU). Unfortunately, none of these botanists provided a detailed written description of the flora or plant communities of this unique area.

Presently, the two areas that are considered to be of State significance in Spencer County are within three miles north of Bloomfield, Grass Township. Only one of these sites has barrens. It is approximately 200 acres in area and has three barrens within it ranging from one-half to five acres. The other site is approximately 150 acres in area. All of the Spencer County post oak flatwoods and barrens, both disturbed and undisturbed, are associated with the McGary silt loam soil type, which has a fragipan.

The overstory in the Spencer County post oak flatwoods are composed of almost pure stands of similar sized post oak (*Quercus stellata* four to fourteen inches dbh and approximately 30 feet high. These are relatively widely spaced and form an open canopy. White oak (*Q. alba*) and shellbark hickory (*Carya laciniosa* and *C. ovata*) are seen occasionally, but none larger than 18 inches dbh was observed. Pin oak (*Q. palustris*) is not encountered in the pure post oak stands but is found in a couple of shallow intermittently ponded sites one to three acres in area where it is abundant; this is where sweetgum (*Liquidambar styraciflua*) is also seen. Cherry-bark oak (*Q. falcata* var. *pagodaefolia*) is rarely encountered and only one black-jack oak (*Q. marilandica*) was ever seen. Shingle oak (*Q. imbricaria*) occurs throughout the flatwoods but seldom reaches 15 feet in height.

The flatwoods characteristically lack a distinct shrub-layer, although some shrubs are present. The most frequently seen shrubs are winged elm (*Ulmus alata*), shining sumac (*Rhus copallina*) and shrubby St. John's wort (*Hypericum prolificum*), which

never gets more than five feet high. Although red cedar (*Juniperus virginiana*) was very conspicuous, fewer than 15 individuals were seen.

The herbaceous layer is sparse and usually lacks a thick leaf litter. Three species of sedges (*Carex caroliniana, Eleocharis verrucosa* and *Luzula acuminata* var. *mesochorea*) are characteristic of the herb layer in the flatwoods. Characteristic forbs include *Gillenia stipulacea, Phlox maculata* and *Pycanthemum flexuosum* and the most common grasses are *Cinna arundinacea* and *Uniola latifolia*. In areas where the wind-swept post oak leaves accumulate, which is mostly around fallen trees and small clumps of shrubs, the slowly decaying leaf litter is thick with little or no herbaceous growth.

False aloe (*Agave virginica*) was very rare in the flatwoods and did not occur at all in the barrens. *Carex bushii*, a state endangered sedge, occurred infrequently throughout the flatwoods and was associated with *C. caroliniana*. The state threatened spiderlily (*Hymenocallis occidentalis*) occurred just beyond, and in terms of elevation—just below, the pure stands of post oak in shallow drainageways.

The barrens are floristic areas that exemplify some unusual characteristics for an Indiana plant community. In spring, some of the barrens have shallow, ombrotrophic (rain fed) vernal pools that presist long enough to have an assemblage of characteristic plants (Figure 1). The elevation gently decreases as one enters the surrounding flatwoods from the barrens. Although the barrens occupy the highest elevational point they are covered with ponded water in late winter and early spring and in fact, one of the barrens is depicted as a "pond" on the Chrisney topographic quadrangle map. In early spring, a moss (*Dichranium scoparium*) grows in dense lush mats around the perimeter of the barrens and may somehow account for the ponding of the water.

FIGURE 1. *Oblique aerial photo of a Spencer County barren covered with water in April, 1983. The surrounding open forest consists of pure stands of post oak* (*Quercus stellata*).

By May, a 12 inch high spike rush (*Eleocharis verrucosa*) forms extensive almost pure stands in the barrens. *Carex annectens* is also a characteristic species at this time. In one barren in a slightly shallower basin 10 to 20 square yards in area where the water was 3 to 6 inches deep, three state endangered species were discovered. They are *Eleocharis wolfii*, which was common to abundant, the small crowfoot (*Ranunculus pusillus*), which was common, and at least 50 individuals of the quillwort (*Isoetes melanopoda*), previously unreported for Indiana. All three of these rare species were growing together in association with *C. annectens* and *Ludwigia palustris*.

By July, most of the above plants have completely withered and poverty grass (*Danthonia spicata*) and litle bluestem (*Andropogon scoparius*) are the characteristic graminoid plants (Figure 2). Small annuals, that are often found on sandstone glades

FIGURE 2. *Spencer County barren dominated by poverty grass* (*Danthonia spicata*) *in July,* 1983.

in southern Illinois and Missouri, such as *Diodea teres, Hypericum drummundii, H. gentianoides*, and the state endangered rushfoil (*Crotonopsis elliptica*) are abundant. These species persist throughout the remainder of the summer and early fall. By early October the species composition has not changed much, although at this time a three awn grass (*Aristida ramosissima*) was first mature enough to identify; as was the small bluecurls (*Trichostema setaceum*) which previously has not been reported for Indiana. At least 100 individuals of the state endangered St. John's wort (*Hyperium denticulatum*) were seen along the perimeter of the barrens immediately adjacent to the post oak flatwoods.

Although post oak flatwoods in Posey County were not identified as such by the land surveyors in the early 1800's (19), their description of the local landscape as generally "thin soil, flatland, oak and hickory" might indicate the presence of the community. In the 1920's Charles Deam collected plants from the area in a habitat described as "low, open post oak flats . . . ". Presently post oak flatwoods are restricted

FIGURE 3. *Oblique arboreal photo taken in August, 1983 depicting the open spacing of the trees in a Posey County post oak flatwoods.*

in Posey County to Point Township, where three significant sites are known. They are almost exclusively associated with Weinbach silt loam, an acid alluvium on old terraces of the Wabash and Ohio Rivers (14). The communities consist of small, level areas (5 to 10 acres) dominated by *Quercus stellata* and an herbaceous flora characterized by a number of prairie species. These communities are noticeably different from surrounding ones not on Weinbach soils, for their open and relatively sunny environment (Figure 3) contrasts with adjacent sites that are densely vegetated with shrubs, vines, and an assortment of tree species. The absence of lower and mid-canopy woody species and the thick, widely spaced branches of the post oak contribute to the open nature of the community. The post oak are not large, averaging fifteen inches dbh. One tree ten inches dbh was cored and determined to be approximately sixty-five years old.

Although the sites rarely flood from overflow of streams, they do collect one to three inches of standing water in winter and spring, due primarily to the presence of a fragipan and the lack of drainage. The almost pure stands of post oak are found on slightly elevated land above the standing water. On the wetter sites, *Quercus falcata* var. *pagodaefolia, Q. bicolor, Q. palustris*, and *Carya laciniosa* are more important.

The communities are floristically unique in Indiana. This is due primarily to the occurrence of prairie species growing with southern bottomland species. Some of the characteristic prairie and dry woodland plants found include *Carex caroliniana, C. Bushii, Baptisia leucantha, Psoralea psoralioides, Solidago rigida, Coreopsis tripteris, Helianthus mollis, Liatris spicata, Phlox pilosa, Euphorbia corollata, Eryngium yuccifolium, Physostegia virginiana, Agave virginica*, and *Gillenia stipulata*. In the scattered wet depressions additional species are found, including *Carex muskingumensis, C. squarrosa, C. Buxbaumii, C. socialis, Cinna arundinacea, Hymenocallis occidentalis, Amorpha fruticosa, Ilex decidua, Boltonia asteroides, Platanthera peromoena, Isoetes melanopoda, Spermacoce glabra*, and *Spigelia marilandica*.

Results and Discussion

A total of 22 potentially significant post oak flatwoods and barrens were field checked and evaluated. The five most significant sites were selected for intensive field surveys. A total of 146 taxa representing 57 families were identified (Table 1). Of particular note are the eleven rare, threatened or endangered species that were discovered; two of which are new to the Indiana flora. The number of non-native species, which included *Achillea millefolium* and *Lonicera japonica*, was low. These aliens were rarely encountered, but since they are not a part of the native flora in these natural communities, they should be exterminated.

Many of the flatwoods that we checked had been intensively timbered and a number of others have been cleared within the past 10 to 20 years for agriculture. Most noteably, these include the Halfmoon Pond Woods discussed by Lindsey et al. (11), Grabert's Woods which was a collection site of Deam's and the famous Scuffle Pond (Nolta Irwin Woods). The Irwin Woods was unfortunately destroyed in 1979. It was visited by botanists attending the 1939 Indiana Academy of Sciences Spring Meeting at New Harmony (20) and contained many rare plants.

The use of the term "barrens" to describe the natural openings surrounded by post oak flatwoods in Spencer County appears to be the best word to describe this community. Both the early land surveyors and former Indiana botanists applied this term to these forest openings. Also in light of Hutchison's (7) excellent, well documented review of the past and present use and meaning of "barrens", it is appropriately used here. It still must be emphasized that the Spencer County barrens vegetation is distinct from the barrens described elsewhere that are dominated by prairie vegetation.

It does appear that fire did play a role, and perhaps still should, in the maintenance of these communities. Both the early land surveyors and Deam in his May 1, 1927 "Woodland Inspection Report" of a tract within S32 T5S R6W made reference to burnt over flats and barrens. Only a few trees with fire scars were noted during this study. The suppression of fires may account for the apparent disappearance of buffalo clover. The absence of fires may also account for the low density of some prairie plants that were seen in Posey County. Since very few "typical" prairie species were found in Spencer County it is difficult to speculate what impact fire cessation has had here.

A few intriguing rare, or otherwise noteworthy, plants were reported historically by Deam in the immediate vicinity of the areas we studied but wre not rediscovered by us. *Lesquerella globosa* was found in 1941 at its only "natural" site outside of the Nashville Basin. Although *Hypericum denticulatum* was rediscovered in Spencer County it was not found in Posey County. *Perideridia americana* was found in 1929, as a single plant, in the Spencer County flats north of Grass. In 1939, in the same area, *Baptisia leucantha* and *Prenanthes aspera* were found assoicated with *Liatris aspera* and *Hypericum denticulatum*. These latter two species were rediscovered in one of the Spencer County barrens north of Bloomfield. It is difficult to believe that we overlooked the conspicuous *B. leucantha* and *P. aspera*, so perhaps they have become locally extirpated. Unfortunately, it also appears that buffalo clover (*Trifolium reflexum* var. *glabrum*) may be extirpated in Indiana. Although it is presently listed as threatened, it has not been reported in the past 50 years. Historically, this species was collected in post oak flatwoods in Posey and Spencer Counties, but we were unsuccessful in our specific attempts to rediscover it. Its disappearance is baffling, particularly since its habitat and historic collection site is still extant and relatively undisturbed. Apparently this species has not fared well throughout most of its range. It is extirpated in Ohio

TABLE 1. *Vascular Flora of Post Oak Flatwoods and Barrens*

Taxa	Spencer County	Posey County
Amaryllidaceae		
Hymenocallis occidentalis	x	x
Hypoxis hirsuta		x
Anacardiaceae		
Rhus copallina	x	
Rhus radicans	x	x
Apocynaceae		
Amsonia tabernaemontana		x
Aquifoliaceae		
Ilex decidua		x
Asclepiadaceae		
Asclepias purpurea		x
Asteraceae		
Achillea millefolium	x	
Antennaria plantaginifolia		x
Bidens sp.	x	
Boltonia asteroides		x
Coreopsis tripteris		x
Cryptotaenia canadensis	x	
Eupatorium perfoliatum	x	
Eupatorium purpureum	x	
Helianthus divaricatus	x	x
Helianthus molllis		x
Hieracium gronovii	x	x
Krigia biflora	x	x
Liatris aspera	x	
Liatris spicata		x
Polymnia canadensis		x
Silphium integrifolium	x	
Solidago nemoralis	x	
Solidago rigida		x
Verbesina helianthoides		x
Araceae		
Arisaema dracontium	x	x
Balsaminaceae		
Impatiens biflora		x
Bignonianceae		
Campsis radicans	x	x
Catalpa speciosa		x
Boraginaceae		
Cynoglossum virginianum		x
Campanulaceae		
Lobelia inflata		x
Caprifoliaceae		
Lonicera japonica	x	x
Symphoricarpos orbiculatus	x	x
Viburnum dentatum		x
Viburnum prunifolium		x
Celastraceae		
Euonymus atropurpureus		x
Cistaceae		
Lechea tenuifolia	x	
Cornaceae		
Cornus florida	x	
Nyssa sylvatica		x
Commelinaceae		
Tradescantia subaspera		x

TABLE 1.—Continued

Taxa	Spencer County	Posey County
Cupressaceae		
Juniperus virginianus	x	
Cyperaceae		
Carex annectens	x	x
Carex bushii	x	x
Carex buxbaumii		x
Carex caroliniana	x	x
Carex cephalophora		x
Carex davisii		x
Carex festucacea		x
Carex glaucophylla	x	
Carex grayii		x
Carex lanuginosa		x
Carex molesta		x
Carex muskingumensis		x
Carex squarrosa	x	x
Eleocharis verrucosa	x	x
Eleocharis wolfii	x	
Luzula echinata var. *mesochorea*	x	x
Ebenaceae		
Diospyros virginiana	x	x
Euphorbiaceae		
Crotonopsis elliptica	x	
Euphorbia corollata	x	x
Fabaceae		
Amorpha fruticosa		x
Apios americana	x	x
Baptisia leucantha		x
Cassia fasiculata		x
Cercis canadensis		x
Desmodium sp.	x	x
Psoralea psoralioides		x
Stylosanthes biflora	x	
Fagaceae		
Quercus alba	x	
Quercus bicolor		x
Quercus falcata var. *pagodaefolia*	x	x
Quercus imbricaria	x	x
Quercus marilandica	x	
Quercus palustris	x	x
Quercus stellata	x	x
Gentianaceae		
Swertia caroliniensis	x	
Gramineae		
Andropogon scoparius	x	
Andropogon virginicus	x	
Aristida ramosissima	x	
Cinna arundinacea	x	x
Danthonia spicata	x	
Hystrix patula		x
Panicum depauperatum	x	x
Sorghastrum nutans		x
Uniola latifolia	x	x
Hamamelidaceae		
Liquidambar styraciflua	x	x
Hypericaceae		
Hypericum denticulatum	x	
Hypericum drummondii	x	
Hypericum gentianoides	x	

TABLE 1.—Continued

Taxa	Spencer County	Posey County
Hypericum prolificum	x	
Iridaceae		
Iris virginica		x
Isoetaceae		
Isoetes melanopoda	x	x
Juglandaceae		
Carya laciniosa	x	x
Carya ovata	x	x
Juncaceae		
Juncus tenuis	x	x
Labiatae		
Physostegia virginiana		x
Prunella vulgaris	x	
Pycnanthemum flexosum	x	x
Scutellaria leonardi	x	x
Scutellaria parvula		x
Trichostema setaceum Houtt.	x	
Lauraceae		
Sassafras albidum		x
Liliaceae		
Allium canadense		x
Polygonatum canaliculatum	x	x
Linaceae		
Linum medium var. *texanum*	x	
Loganiaceae		
Spigelia marilandica		x
Moraceae		
Maclura pomifera	x	
Oleaceae		
Fraxinus pennsylvanica		x
Onagraceae		
Circaea quadrisulcata		x
Ludwigia alternifolia		x
Ludwigia palustris	x	
Oenothera tetragona	x	x
Orchidaceae		
Platanthera peramoena		x
Oxalidaceae		
Oxalis stricta	x	
Polemoniaceae		
Phlox glaberrima	x	x
Phlox maculata	x	x
Phlox pilosa		x
Polygalaceae		
Polygala sanginea	x	
Primulaceae		
Lysimachia lanceolata	x	x
Lysimachia nummularia		x
Rannunculaceae		
Ranunculus pusillus	x	
Rhamnaceae		
Ceanothus americanus		x
Rosaceae		
Amelanchier sp.	x	
Crataegus sp.	x	x
Potentilla simplex	x	x
Prunus serotina	x	
Rosa caroliniana	x	x

TABLE 1.—Continued

Taxa	Spencer County	Posey County
Rubus sp.	x	x
Rubiaceae		
Spermacoce glabra		x
Saxifragaceae		
Heuchera americana	x	
Scrophulariaceae		
Gerardia sp.	x	
Gratiola neglecta	x	x
Penstemon digitalis	x	x
Ulmaceae		
Ulmus alata	x	
Ulmus americana		x
Umbelliferae		
Cryptotaenia canadensis		x
Eryngium yuccifolium		x
Thaspium trifoliatum		x
Rubiaceae		
Cynoglossum virginianum	x	
Galium concinnum		x
Houstonia purpurea		x
Vitaceae		
Parthenocissus quinquefolia	x	x
Vitis sp.	x	x
Violaceae		
Viola sagittata	x	x
Viola triloba		x
Urticaceae		
Boehmeria cylindrica		x

and New York and probably Kentucky, Iowa, and South Dakota. Only one extant site is known from Illinois where historically it occurred in 19 counties.

None of the post oak flatwoods and barrens are presently protected as state natural areas. However, efforts towards their protection are being taken through direct acquisition from willing sellers by the Department of Natural Resources' Division of Nature Preserves and The Nature Conservancy. Some owners have also agreed to protect their post oak flatwoods voluntarily through the Indiana Natural Areas Registry. Continued efforts to protect these unique elements of Indiana's natural heritage should be supported by the public and private sectors to insure their existence in perpetuity.

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Glades of the Knobstone Escarpment in Indiana

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Introduction

Glades are small natural openings within the forest with bedrock at or near the surface. In southern Indiana, glades usually occur on steep south or west-facing slopes, and usually are dominated by prairie grasses and forbs. Most of those found thus far occur on limestone (1), but a few occur on sandstone (3). Recently, glades have been located on sandstone, siltstone and shale on the Knobstone Escarpment in Clark, Floyd, and Jackson Counties of southcentral Indiana. In this paper, the methods used to locate and evaluate the Knobstone glades are discussed, and a preliminary species list is presented.

Methods

A systematic search for glades was undertaken in Floyd County (11), Clark County (12), and Jackson and Washington Counties (2). The methods used were similar to those used to find glades in Harrison, Perry and Crawford Counties, Indiana (1,3). The most recent aerial photographs available at the Agriculture Stabilization and Conservation Service offices in each county were examined, in conjunction with the 7.5 minute United States Geological Survey topographic quadrangle maps. Openings in the forest were carefully examined in an effort to locate those with potential to be natural. Openings that were obviously man-made were eliminated from consideration. Older aerial photographs were examined to further evaluate the past history of these openings.

Sites determined to be potential glades were then evaluated during a field visit. A total of thirty-three potential glades were visited. Factors used to help evaluate the quality of these areas included presence or absence of alien species, richness of native species, amount of woody encroachment, and presence or absence of obvious signs of disturbance by man.

Results

Nineteen glades were located—three in Jackson Conty, one in Clark County, and fifteen in Floyd County. In general, all of these glades are very similar to one another. They are very xeric sites, with much bedrock (siltstone, shale, sandstone) exposed, the soil is a shallow Weikert Channery Silt Loam (17), and the vegetation is sparse. The overstory consists primarily of chestnut oak (*Quercus prinus*), Virginia pine (*Pinus virginiana*), post oak (*Quercus stellata*) and black jack oak (*Q. marilandica*). Blueberries (*Vaccinium vacillans* and *V. stamineum*) are the most common shrubs. The most characteristic forbs are goat's rue (*Tephrosia virginiana*), knobs goldenrod (*Solidago sphacelata*), dittany (*Cunila origanoides*), and flowering spurge (*Euphorbia corollata*), and the most common grasses were poverty grass (*Danthonia spicata*) and little bluestem (*Andropogon scoparius*). All together thirty-five native grasses and forbs were identified (Table 1).

TABLE 1. *A preliminary species list for the Knobstone Escarpment glades in Jackson, Clark, and Floyd Counties, Indiana.*

TAXON	Jackson Co. Glades	Clark Co. Glades	Floyd Co. Glades
Acer rubrum[3]		x	x
Acer saccharum	x		
Agave virginica[3,4]			x
Agrimonia pubescens		x	x
Amelanchier sp.[3]	x	x	
Andropogon scoparius[3,4]	x	x	x
Anemone virginiana[3,4]			x
Antennaria plantaginifolia[3]	x	x	x
Apocynum cannabinum[3]	x		x
Asclepias tuberosa[3]	x		x
Asclepias viridiflora[2,3]			x
Ascyrum hypericoides[3]			x
Aster patens[3,4]		x	
Baptisia leucantha[3]			x
Carex sp.	x		
Carya ovata[3]		x	x
Cassia fasciculata[3]		x	
Celastrus scandens		x	
Cercis canadensis[3,4]			x
Cornus florida[3]	x	x	x
Conopholis americana		x	
Cunila origanoides[3,4]	x	x	x
Danthonia spicata	x	x	
Desmodium sp.		x	
Diospyros virginiana[3]			x
Euphorbia corollata[3,4]	x	x	x
Fagus grandifolia[3]	x	x	
Fraxinus americana[3]			x
Gaylussacia baccata	x		
Helianthus divaricatus[3]	x	x	x
Helianthus hirsutus[3]		x	
Heuchera sp.			x
**Hieracium venosum*		x	x
Hieracium sp.		x	
Houstonia longifolia			x
Houstonia sp.		x	
Hypericum punctatum[3]		x	
Juniperus virginiana[3,4]	x	x	x
Krigia dandelion[3]			x
Lespedeza hirta[3]		x	x
Lespedeza sp.	x		x
**Liatris squarrosa*[3,4]	x		x
Monarda fistulosa[3,4]		x	x
Nyssa sylvatica	x	x	x
Ostrya virginiana[3]	x		x
Panicum sp.	x		x
Parthenocissus quinquefolia		x	
Penstemon sp.[2]			x
Pinus virginiana		x	x
Prunus serotina			x
Quercus marilandica[3]	x	x	x
Quercus prinus	x	x	x
Quercus borealis var. *maxima*			x
Quercus stellata		x	x
Quercus velutina[3]		x	x
Rhus copallina[3]		x	x

TABLE 1.—Continued

TAXON	Jackson Co. Glades	Clark Co. Glades	Floyd Co. Glades
Rhus radicans		x	
Rosa sp.		x	x
Sassafras albidum[3]	x	x	x
Sanicula marilandica			x
Smilax sp.	x	x	x
Solidago sphacelata	x	x	x
Stylosanthes biflora[3]	x		x
Swertia carolinensis[3,4]	x		
Tephrosia virginiana[3]	x	x	x
Thaspium sp.	x		
**Vaccinium arboreum*[3]			x
Vaccinium stamineum[3]			x
Vaccinium arboreum[3]	x	x	x
Viburnum acerifolium	x		
Viburnum rufidulum[3,4]			x
Vitis sp.	x	x	x

1. Nomenclature according to Gleason and Cronquist (10).
2. Taxon observed only on one site—a "prairie glade".
3. Taxon also reported from Perry and Crawford County glades and barrens (3).
4. Taxon also reported from Harrison County limestone glades (1).

* = on the "Preliminary list of endangered and threatened vascular plants of Indiana" (4,5).

Several of these species are considered rare in Indiana, including *Hieracium venosum, Liatris squarrosa*, and *Vaccinium arboreum* (4,5).

Discussion

The Knobstone Escarpment is a prominent topographic feature which defines the eastern edge of the Norman Upland where it abruptly drops into the Scottsburg Lowland (14). The bedrock of this escarpment consists mostly of relatively resistant siltstone and sandstone, interbedded with softer non-calcareous shales. The glades of the Knobstone Escarpment have more exposed bedrock, sparser vegetative cover, and a lower species richness than the other Indiana glades reported on previously. For example, only eight of the forb and grass species reported from limestone glades in Harrison County occur on the "knobstone glades" (1, Table 1). The Knobstone glades appear to be similar to the "barrens" described for Illinois by Vestal (17), who spoke of a "high proportion of forest herbs, and lacking many prairie plants." An (apparently) similar community was mentioned, but not floristically described, by Braun in The Knobs Region of Ohio (6).

Glades were found primarily in Floyd County, but some remnants were found in Jackson County, approximately 35 miles northwest of Floyd County. The only obvious difference was the absence of native populations of *Pinus virginiana* on the Jackson County sites. Structurally and floristically, these glades appear to be very similar.

The Knobstone glades may be remnants of a formerly much more extensive glade and barren flora and vegetation, as appears to be the case in other parts of southern Indiana (1,3,7,13). A few forbs, such as *Agave virginica* and *Baptisca leucantha*, and a lush prairie grass cover, occur on Bald Knob in Floyd County, on a remnant of prairie glade degraded (and now probably maintained) by herbicide spraying. This rem-

nant, on a topographic feature named "Bald Knob", lead to speculation of a more prairie-like community in presettlement times. Other evidence suggesting the former existence of barrens and glades in Southern Indiana include the old collections from Floyd County of prairie-glade species such as *Helianthus occidentalis, Ratibida pinnata, Silphium terebinthinaceum, Solidago rigida, Liatris spicata, L. aspera*, and *Buchnera americana* (8). However, none of these species was relocated on any of the Knobstone glade remnants.

As is the case for glades and barrens all over the Midwest, glades on the Knobstone Escarpment have nearly disappeared since settlement. Fire suppression and cultivation are believed to be the primary cause of their disappearance (7,9,13,15). Based on the lack of disturbance and absence of alien species, the remnants described here appear to be of high quality. They are becoming smaller due to encroachment by woody species, which shade out the forbs and grasses. Erosion is also a threat in some of the areas. Protection and management of these communities will be necessary if they are to continue to exist in Indiana.

Acknowledgments

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A Study of the Natural History of Naturally Occurring Populations of *Magnolia tripetala* L. in Indiana

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Introduction

A single location for *Magnolia tripetala* L. (umbrella magnolia) was reported for Indiana by Charles Deam in 1945 (3). Currently, the known distribution of *M. tripetala* in Indiana is confined to seven sites in a few ravines near the Ohio River in Crawford County. The current status of *M. tripetala* and the surrounding plant community was evaluated to aid in future study, protection and management of this species, which is endangered in Indiana.

Location

The study site is located in Crawford County, Indiana (Figure 1). The seven known locations of *M. tripetala* occurrence are located at the following coordinates:

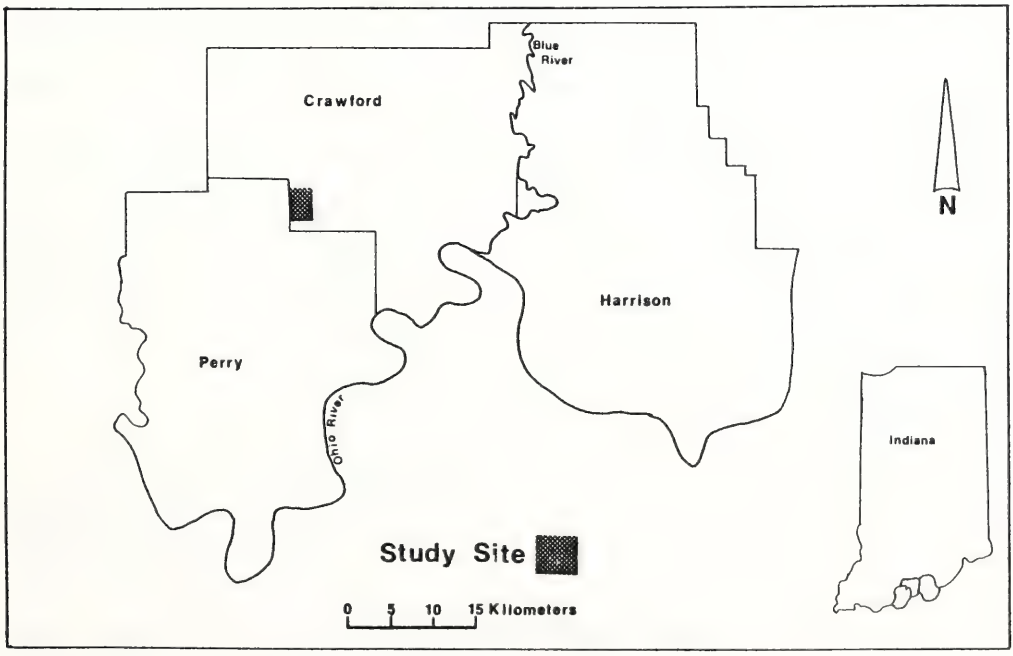

FIGURE 1. *Location of study area.*

Branchville 7 1/2-minute Topographic Quadrangle

1) Stinking Fork Ravine, NW 1/4, Sec. 20 and NE 1/4, Sec. 19, T3S, R1W. (Hoosier National Forest)
2) Box Canyon Magnolia Area, NE 1/4, Sec. 30, T3S, R1W (Private Ownership)
3) I-64 Site, SE 1/4, Sec. 19 and SW 1/4, Sec. 20, T3S, R1W (Private Ownership)
4) Potts Creek Magnolia Stand, SW 1/4 Sec. 30, T3S, R1W (Hoosier National Forest)

Taswell 7 1/2-minute Topographic Quadrangle

1) Keysacker Magnolia Site, SE 1/4, Sec. 17, and NE 1/4, Sec. 20, T3S, R1W (Hoosier National Forest and Private Ownership)
2) Russell Branch Site, NW 1/4, Sec. 17, T3S, R1W (Hoosier National Forest)
3) Magnolia Hollow, SW 1/4, Sec. 17, T3S, R1W (Private Ownership)

Plant Community

There was evidence of selective harvesting of timber in all the ravines where *M. tripetala* occurred. The severity and history of disturbance has varied between each ravine. The most severe human-induced disturbances appeared to be Interstate 64 bisecting the I-64 site and very heavy timber harvesting at Magnolia Hollow. The Magnolia Hollow site was the location originally described by Deam (4) and further detailed by Lindsey, Schmelz and Nichols (6).

The tree stratum was found to be dominated by *Acer saccharum* Marsh., *Fagus grandifolia* Ehrh., *M. tripetala* and *Acer rubrum* L. The sapling and seedling strats were predominantly composed of *A saccharum* and *A. rubrum.*

There were 157 species of vascular plants identified from the study area. Voucher specimens were collected and deposited in the Indiana State University herbarium. Several species of special concern were found within the study site. Species given special status by Bacone and Hedge (1) are listed in Table 1. All nomenclature follows Kartesz and Katesz (5).

TABLE 1. *Species of special concern occuring in study site. Status is that given by Bacone and Hedge (1).*

SPECIES	STATUS
Antennaria solitaria Rybd.	State Threatened
Dodecatheon frenchii (Vasey) Rydb.	State Endangered
Heuchera parviflora Bartl.	State Endangered
Hydrastis canadensis L.	Special Concern-Federal
Kalmia latifolia L.	State Threatened
Lycopodium selago L. var. selago (Beauv.) Desv.	State Endangered
Magnolia tripetala L.	State Endangered
Panax quinquefolius L.	Special Concern-Federal
Platanthera peramoena (Gray) Gray	Special Concern-Federal
Solidago hispida Muhl.	State Threatened
Synandra hispidula (Michx.) Baill	Special Concern-Federal

Ailanthus altissima (Mill.) Swingle has become naturalized in all of the ravines where *M. tripetala* occurs. This species has usually been associated with the secondary growth of waste areas (7). There is some evidence that *A. altissima* is directly competing with *M. tripetala.*

Permanent Plots

A total of ten permanent plots were located in four of the ravines, where *M. tripetala* occurs. Circular plots were laid out, each with a radius of 9 m. The center of each plot was marked by an 18-inch brass-coated stake. The stakes were driven completely into the ground, to avoid problems with vandalism and to maintain the natural character of the areas. Future relocation of the center markers would be aided

by the use of a metal detector. A detailed description of the permanent plots and a location map are located in the Indiana State University Library (2).

The permanent plots were located at sites of good *M. tripetala* growth and reproduction. This will enable future monitoring of what is currently prime habitat for *M. tripetala*. The permanent plots were also placed to include sites where *A. altissima* has become established.

Management Recommendations

Currently, *M. tripetala* populations appear to be stable in Indiana. Reproduction by runners and seeds seems to be adequate to maintain or even expand the populations. However, the limited distribution and the species low tolerance to disturbance warrants the protection of all sites of natural occurrence.

The steep slopes and associated soils of the ravines are highly susceptible to damage by human traffic. There has been increasing visitation to the *M. tripetala* sites in recent years. If feasible, consideration should be given to a managed trail system, which avoids sensitive areas.

Efforts should be maintained to monitor *M. tripetala* and the other species of special concern. The naturalization of *A. altissima* should be closely followed. If trends continue, *A. altissima* should be eliminated as a competitor with *M. tripetala*. *Lycopodium selago* var. *selago, Dodecatheon frenchii* and *Heuchera parviflora* are all found in shallow soil deposits on the sandstone cliffs. These species are extremely sensitive to human disturbance and increased human traffic along the cliff faces may cause irreparable damage.

Ther majority of *M. tripetala* sites are on Hoosier National Forest property. It is important that these sites and a surrounding buffer zone be given a protected status by the U.S. Forest Service. Voluntary landowner protection or acquisition of sites in private ownership should also be given priority. The proximity, similar species composition and similar geological history of the *M. tripetala* sites, Hemlock Cliffs and Yellow Birch Ravine suggest the possibility of a management plan that would encompass all three sites.

Acknowledgments

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Composition Gradients in Forest Canopy and Groundlayer Vegetation within a White River Floodplain Forest

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Introduction

While much research has been done to describe upland forests in Indiana, much less has been done with floodplain forest in the state. Two published papers are all that apparently exist. Lee (1945) reported on the floodplain vegetation of the White River, while Lindsey, *et al.* (1961), described floodplain vegetation along the banks of the Tippecanoe and Wabash Rivers (5,6).

The site described in this paper was discovered as a result of a natural areas inventory for Marion County performed by the Division of Nature Preserves of the Indiana Department of Natural Resources (Bacone 1980) (1). The site was also described in a natural areas survey for the west fork of White River conducted for the Indiana Department of Natural Resources performed by Hollett, (1980) (4).

Study Area

The study site is located in northern Marion County in the N½, NE¼, Sec. 16, T 17N, R4E (Figure 1). The site is composed of two sections. The larger section is floodplain forest of approximately 15 to 20 acres. It is bounded on the west side by the White River, the east side by an upland transition slope, and partially on the north side by a power line and natural gas pipeline right-of-way which follows the Hamilton-Marion County line. The floodplain becomes narrower at the south end of the tract and finally becomes a slope at the river bank. The entire top of the slope along the east side of the floodplain is the site of apartment complexes and has been partially backfilled.

The floodplain section of the site shows a good diverity of tree species. A narrow band at the river bank is frequently flooded and is dominated by small-to-medium silver maple. Farther back from the river bank, the site is better drained with other tree species becoming important. While silver maple is still presnt, large cottonwood, hackberry, and sycamore increase in importance. Such tree species as box-elder, paw paw, and American elm are represented in the smaller size classes. Floodplain depressions of medium width which occur at intervals contain black ash, swamp white oak, sycamore and other very wet site species. The herb layer contains such wet site species as Canada nettle, and touch-me-not.

The upland forest area, while small in extent provides an abrupt contrast to the floodplain forest. The area is dominated by large sugar maple, beech, and red oak with some white oak. Flowering dogwood, ironwood, and other species are represented in the smaller size classes. Such species as bloodroot and hepatica are present in the herbaceous understory.

Methods

For sampling trees, two parallel transects were laid out which started at the river

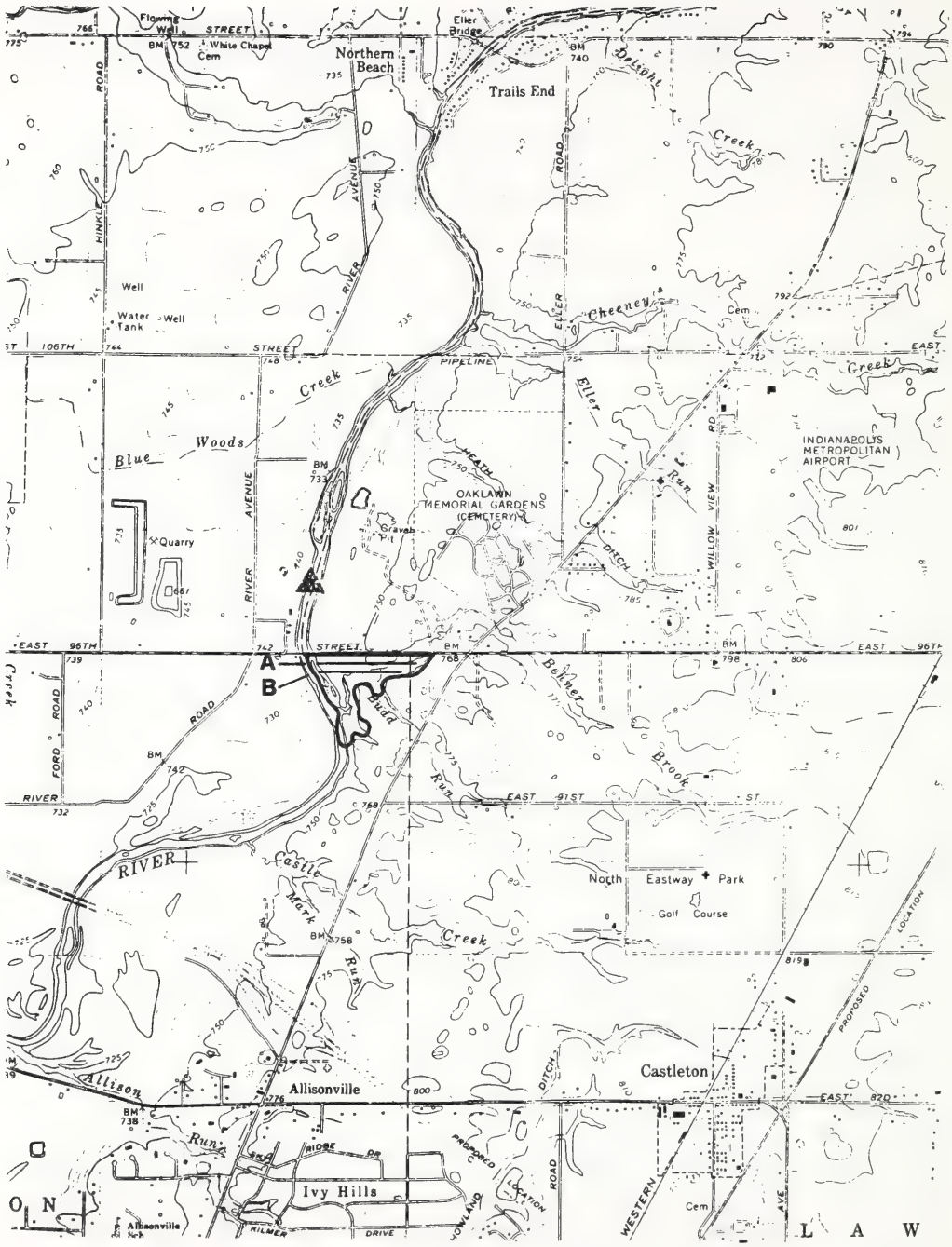

FIGURE 1. *Study site location of Bud Run Floodplain Forest, Marion County, Indiana, showing transect locations. Fishers 7 1/2-minute quandrangle. Contour interval 5 feet.*

bank and ran eastward before ending on the upland part of the site (Figure 1). The transects were then subdivided into 25-meter lengths by use of a 50-meter tape. The species and dbh of each tree over 10 cm (4 inches) diameter within a 5-meter perpendicular distance on either side of the tape was recorded separately for each 25-meter sub-section. A 2.5-meter telescoping pole was used to measure the 5-meter distance from the tape.

Sampling of shrubs was performed by recording the number of individuals less

than 1 meter tall of each species within 2.5 meters of one side of the tape along a 10 meter length for each 25-meter sub-section.

The groundlayer was sampled by recording the number of individuals and estimated ground cover for each species in square meter plots. These plots were located at the end of each 25-meter section and were set up with portable plot frames. Three samplings were conducted during the growing season in May, August, and October.

Results

Species composition varied along floodplain gradients for each of the herbaceous, shrub and canopy tree strata. Distance from the river, internal and surface drainage patterns, location of surface debris, and presence or absence of canopy openings were the prominent factors controlling microsite differences.

Groundlayer Composition

The groundlayer included all herbaceous individuals plus woody plants less than 0.5 m tall. The sixty-nine species or species groups which contributed to the groundlayer vegetation are arranged in a gradient or continuum sequence in Table 1. Included were two species of mosses and *Selaginela*, eight grass and sedge species, six species of shrubs, four tree species and 49 broadleafed herbs.

TABLE 1. *Changes in herbaceous composition along transects from the White River across the floodplain into the upland forest. Values are average importance percentages derived from averaging relative density and estimated relative cover for both transects combined.*

Species	Distance in Meters from White River							Average Percent Importance
	50	100	150	200	250	300	350	
Carex laxiflora Lam.	0.20	—	—	—	—	—	—	0.03
Ambrosia trifida L.	0.21	—	—	—	—	—	—	0.03
Campanula americana L.	0.47	—	—	—	—	—	—	0.07
Cinna arundinacea L.	3.14	—	—	—	—	—	—	0.45
Lysimachia nummularia L.	4.84	—	—	—	—	—	—	0.69
Menispermum canadense L.	0.22	0.72	—	—	—	—	—	0.13
Unidentified moss spp.	0.89	0.19	—	0.18	—	—	—	0.18
Eupatorium rugosum Houtt.	1.21	0.31	—	0.98	—	—	—	0.36
Elymus virginicus L.	8.20	11.58	11.63	1.30	—	—	—	4.67
Polygonatum biflorum (Walt.)	0.58	0.70	3.89	1.05	1.08	—	—	1.04
Rudbeckia laciniata L.	11.15	0.89	4.61	3.62	9.40	—	—	4.24
Chaerophyllum procumbens (L.) Crantz	1.65	—	0.41	0.77	0.23	0.15	—	0.46
Cryptotaenia canadensis (L.) DC.	1.64	0.88	—	0.67	—	1.31	—	0.64
Geum canadense Jacq.	1.55	—	0.14	—	2.52	1.82	—	0.86
Parthenocissus quinquefolia (L.) Planch.	1.07	6.58	0.95	—	0.56	4.15	—	1.90
Viola papilionacea Pursh.	5.16	1.66	2.28	—	13.33	1.36	—	3.40
Pilea pumila (L.) Gray	0.36	—	15.84	3.99	1.25	15.12	—	5.22
Solidago sp.	2.74	2.68	0.25	0.42	0.63	0.27	—	1.00
Urtica dioica L.	5.09	3.90	4.15	4.46	8.76	1.66	—	4.00
Impatiens pallida Nutt.	8.36	21.25	10.87	12.82	10.69	6.85	—	10.08
Laportea canadensis (L.) Wedd.	9.01	11.58	11.66	16.08	20.41	17.56	—	12.33
Viola sp.	0.14	—	—	2.85	1.92	—	0.18	0.73
Polygonum sp.	4.09	0.22	.023	1.99	—	—	0.31	0.98
Aster sp.	2.09	—	0.24	4.24	0.96	0.27	0.37	1.11
Rhus radicans L.	3.72	0.20	—	—	—	1.17	3.12	1.17
Viola canadensis L.	17.08	8.97	11.68	2.07	5.62	—	0.80	6.60
Smilax hispida Muhl.	0.85	0.21	4.52	0.68	0.32	0.45	0.99	1.15
Osmorhiza longistylus (Torr.) DC.	1.53	3.60	1.05	1.53	0.44	0.31	1.43	1.21

TABLE 1.—Continued

Species	Distance in Meters from White River							Average Percent Importance
	50	100	150	200	250	300	350	
Sanicula canadensis L.	0.78	8.94	0.63	7.56	1.85	10.34	3.12	4.75
Galium aparine L.	1.25	1.40	7.37	15.41	2.60	5.31	4.94	5.47
Asarum canadense L.	—	11.99	2.57	—	0.22	8.82	24.80	6.91
Boehmeria cylindrica (L.) Sw.	—	0.31	—	—	—	0.51	—	0.12
Sambucus canadensis L.	—	—	0.36	—	—	—	—	0.05
Glechoma hederacea L.	—	—	0.37	—	—	—	—	0.05
Polygonum virginianum L.	—	—	0.39	—	—	—	—	0.06
Isopyrum biternatum (Raf.) T. & G.	—	—	0.22	0.39	—	—	—	0.09
Tradescantia virginiana L.	—	—	0.72	—	—	—	0.37	0.16
Verbesina alternifolia (L.) Britt.	—	—	0.42	0.76	—	—	—	0.17
Euonymus obovatus Nutt.	—	—	0.18	0.24	—	0.33	0.53	0.18
Ipomoea pandurata (L.) G.F.W. Meyer	—	—	0.17	1.96	0.69	—	—	0.40
Ranunculus septentrionalis Poir.	—	—	0.14	0.58	1.60	1.12	—	0.49
Anemonella thalictroides (L.) Spach.	—	—	2.16	—	—	—	0.25	0.71
Thalictrum revolutum DC.	—	—	—	0.29	—	—	—	0.04
Camassia scilloides (Raf.) Cory.	—	—	—	11.99	—	—	—	1.71
Hydrophyllum macrophyllum Nutt.	—	—	—	1.28	11.13	10.10	24.93	6.76
Carex hirtifolia Mackenzie.	—	—	—	—	0.22	—	—	0.03
Prunella vulgaris L.	—	—	—	—	0.25	—	—	0.04
Arisaema dracontium (L.) Schott.	—	—	—	—	0.30	—	—	0.04
Carex jamesii Schw.	—	—	—	—	0.43	—	—	0.06
Selaginella apoda (L.) Spring.	—	—	—	—	0.69	—	—	0.10
Carex grisea Wahl.	—	—	—	—	0.30	0.40	—	0.10
Asimina triloba (L.) Dunal.	—	—	—	—	0.46	1.09	—	0.22
Phlox divaricata L.	—	—	—	—	—	0.20	—	0.03
Cornus florida L.	—	—	—	—	—	0.28	—	0.04
Carex sp.	—	—	—	—	—	0.65	—	0.09
Cercis canadensis L.	—	—	—	—	—	0.97	—	0.14
Silene stellata (L.) Ait.	—	—	—	—	—	1.01	—	0.14
Sanguinaria canadensis L.	—	—	—	—	—	1.17	0.42	0.23
Geranium maculatum L.	—	—	—	—	—	1.66	9.75	1.63
Arisaema triphyllum (L.) Schott.	—	—	—	—	—	—	0.30	0.04
Acer saccharum Marsh.	—	—	—	—	—	—	0.32	0.05
Aristolochia serpentaria L.	—	—	—	—	—	—	0.38	0.05
Panicum sp.	—	—	—	—	—	—	1.17	0.17
Trillium recurvatum Beck.	—	—	—	—	—	—	2.10	0.30
Hepatica acutiloba DC.	—	—	—	—	—	—	3.85	0.55
Smilacina racemosa (L.) Desf.	—	—	—	—	—	—	3.93	0.56
Viburnum prunifolium L.	—	—	—	—	—	—	4.48	0.64
Stellaria sp.	—	—	—	—	—	—	6.66	0.95
Undetermined spp.	0.91	1.09	—	—	0.55	4.01	0.23	0.97

Overall, *Laportea canadensis* and *Impatiens pallida* were the dominant species with an average combined importance value of 22.4% (Table 1). Important subdominants include *Viola canadensis, Galium aparine, Pilea pumila, Sanicula canadensis, Elymus virginicus, Rudbeckia laciniata* and *Urtica dioica* with a combined average importance of 35.0%. Collectively, these nine most important species comprise 57.4% of the groundlayer community. The ten woody species were spotty in distribution and had a combined importance of only 5.5%, with *Parthenocissus quinquefolia, Rhus radicans* and *Smilax hispida* contributing 4.1%. This illustrates the paucity of woody seedlings on frequently-flooded landscapes.

Several species had locally high importances due to large colonies falling into one or two sample plats. Examples include *Lysimachia nummularia* near the river edge,

Viola papilionacea near the river edge and in a back water depression below the upland, and *Camassia scilloides* near the middle of the floodplain.

The groundlayer vegetation shifts sharply in composition from the floodplain to the upland sites (Table 1). Large colonies of *Hydrophyllum macrophyllum* and *Asarum canadensis* dominate the upland community at a combined importance of 49.75%. Subdominant species are *Geranium maculatum, Stellaria* sp., *Galium aparine, Viburnum prunifolium, Smilacina racemosa* and *Hepatica acutiloba* collectively total 33.6% importance. All of these species are typical of upland forests of the midwest. Floodplain species were absent from the upland, or present at very low importance.

Shrub Layer Composition

Although 21 woody species were encountered in the combined plots of both transects, densities were very low in the floodplain community. Only 45 individuals were distributed among only 8 species (Table 2). In contrast the upland slope community contained 208 individuals representing 18 species, almost half of which were *Acer saccharum* seedlings.

TABLE 2. *Changes in densities of woody species within the shrub stratum (>0.5<3m. tall) from the White River across the floodplain into the upland forest.*

	Distance in Meters from White River							
Species	50	100	150	200	250	300	350	Total
Smilax hispida Muhl.	1	—	10	—	—	2	2	15
Celtis occidentalis L.	1	3	—	—	—	5	3	12
Aesculus glabra Willd.	1	8	—	—	—	—	—	9
Parthenocissus quinquefolia L. Planch.	1	—	—	2	—	—	—	3
Fraxinus quadrangulata Michx.	—	4	—	—	—	—	—	4
Lindera benzoin L. Blume.	—	—	5	5	—	2	14	26
Asimina triloba (L.) Dunae.	—	—	—	1	1	22	—	24
Acer negundo L.	—	—	—	2	—	6	—	8
Crataegus sp. L.	—	—	—	—	—	1	—	1
Euonymus obovatus Nutt.	—	—	—	—	—	1	—	1
Platanus occidentalis L.	—	—	—	—	—	1	—	1
Viburnum prunifolium L.	—	—	—	—	—	—	13	13
Staphylea trifoliata L.	—	—	—	—	—	—	12	12
Ulmus rubra Muhl.	—	—	—	—	—	—	11	11
Ostrya virginiana (Mill.) K. Koch.	—	—	—	—	—	—	5	5
Cornus sp. L.	—	—	—	—	—	—	2	2
Carya ovata Mill.	—	—	—	—	—	—	1	1
Cornus florida L.	—	—	—	—	—	—	1	1
Juglans nigha L.	—	—	—	—	—	—	1	1
Quercus muhlenbergii Engelm.	—	—	—	—	—	—	1	1
Total	4	15	15	10	1	56	152	253

Only four species of true shrubs and vines were encountered, with the balance tree seedlings. Of these, only *Lindera benzoin* and *Smilax hispida* contained more than three individuals. *Fraxinus quadrangulata* was the only species not expected to occur in floodplain habitats.

Canopy Tree Composition

Twenty-six species contributed to the tree stratum (Table 3), but four of these were large-sized shrubs or lianas. Size-class distributions for individuals over 5 cm

TABLE 3. *Size-class distribution of tree species above 5 centimeters (2 inches) dbh. Data are combined values for both transects across the floodplain from the White River into the upland forest.*

Species	Size Class in Centimeters									Total Stems
	5-10	10-20	20-30	30-40	40-60	60-80	80-100	100-120	120	
Acer negundo L.	45	26	10	8	8	—	—	—	—	93
Celtis occidentalis L.	34	22	13	8	5	2	2	—	—	86
Aesculus glabra Willd.	26	8	2	2	6	—	—	—	—	44
Acer saccharum Marsh.	12	8	2	1	3	—	—	—	—	26
Acer saccharinum L.	14	—	4	1	2	1	1	1	—	24
Ulmus americana L.	7	3	3	2	1	—	—	—	—	16
Fraxinus nigra Marsh.	—	3	3	3	2	—	—	—	—	11
Platanus occidentalis L.	1	—	—	—	—	2	2	1	2	8
Fagus grandifolia Ehrh.	1	1	—	1	2	1	1	—	—	7
Carpinus caroliniana Walt.	5	2	—	—	—	—	—	—	—	7
Fraxinus americana L.	—	1	1	1	2	—	—	—	—	5
Juglans nigra L.	—	2	1	2	—	—	—	—	—	5
Other species	19	3	2	—	1	2	—	—	—	27
Total	164	79	41	29	28	8	6	2	2	359

[1]Other species in descending order: Asimina triloba (L.) Dunal.; Fraxinus pennsylvanica Marsh.; Ostrya virginiana (Mill.) K. Koch; Quercus bicolor Willd.; Cercis canadensis L.; Parthenocissus quinquefolia L.; Q. marcrocarpa Michx.; Ulmus rubra Muhl.; Vitis sp. L.; Cornus florida L.; Populus deltoides Bartr.; Q. alba L.; Rhus radicans L.; Staphylea trifoliata L.

(2 inches) dbh are listed by species in Table 3. By density, *Acer negundo* and *Celtis occidentalis* predominate with a combined total of 49.9% of the stems. By size-class, 45.7% of the stems are under 10 cm (4 inches) dbh, with *A. negundo, C. occidentalis* and *Aesculus glabra* the major contributors.

Large individuals of several species were present, including two *Platanus occidentalis* at 122-cm (48.0 inches) dbh and one at 105 cm (41.1 inches). Several larger stems of sycamore occurred outside the plots. *Acer saccharinum* reached 103 cm (40.6 inches); *C. occidentalis* 90 cm (35.4 inches); the largest *A. glabra* was 59.0 (23.2 inches) with five others over 40 cm; and *A. negundo* 49 cm (18.9 inches). A lone beech on the floodplain was 89 cm (35.0 inches), perhaps signifying establishment two centuries or more ago when flooding levels, frequencies and durations were much different than those occurring today. One *Parthenocissus quinquefolia* growing on a large hackberry tree was taped at 15.9 cm (6.2 inches) dbh.

Figure 2 illustrates continuum-type changes in basal area contributions for the 16 most prevalent tree species. *Acer saccharinum, Aesculus* and *Celtis* dominate the stand near the river bank; with a more mixed community of *Celtis, A. negundo, Platanus, Juglans, Ulmus* and *Fraxinus* occurring near the middle of the floodplain. Back-water depressions near the upland slope contained a preponderance of *Fraxinus nigra, Quercus bicolor* and *Populus deltoides*. The mesophytic upland community was dominated by *Fagus, Acer saccharum*, and *Q. alba*, with *Carpinus* and *Ostrya* in the understory.

Juglans, Ulmus and *A. negundo* were the widest amplitude species, each ranging across most of the transect lengths, but at low basal area contributions (Figure 2). Large pulses of basal area frequently result from one or two very large trees at a given location. The presence of *Fagus* on the floodplain represents the single large tree mentioned above. Nomenclature follows Gleason and Cronquest (1963) (3).

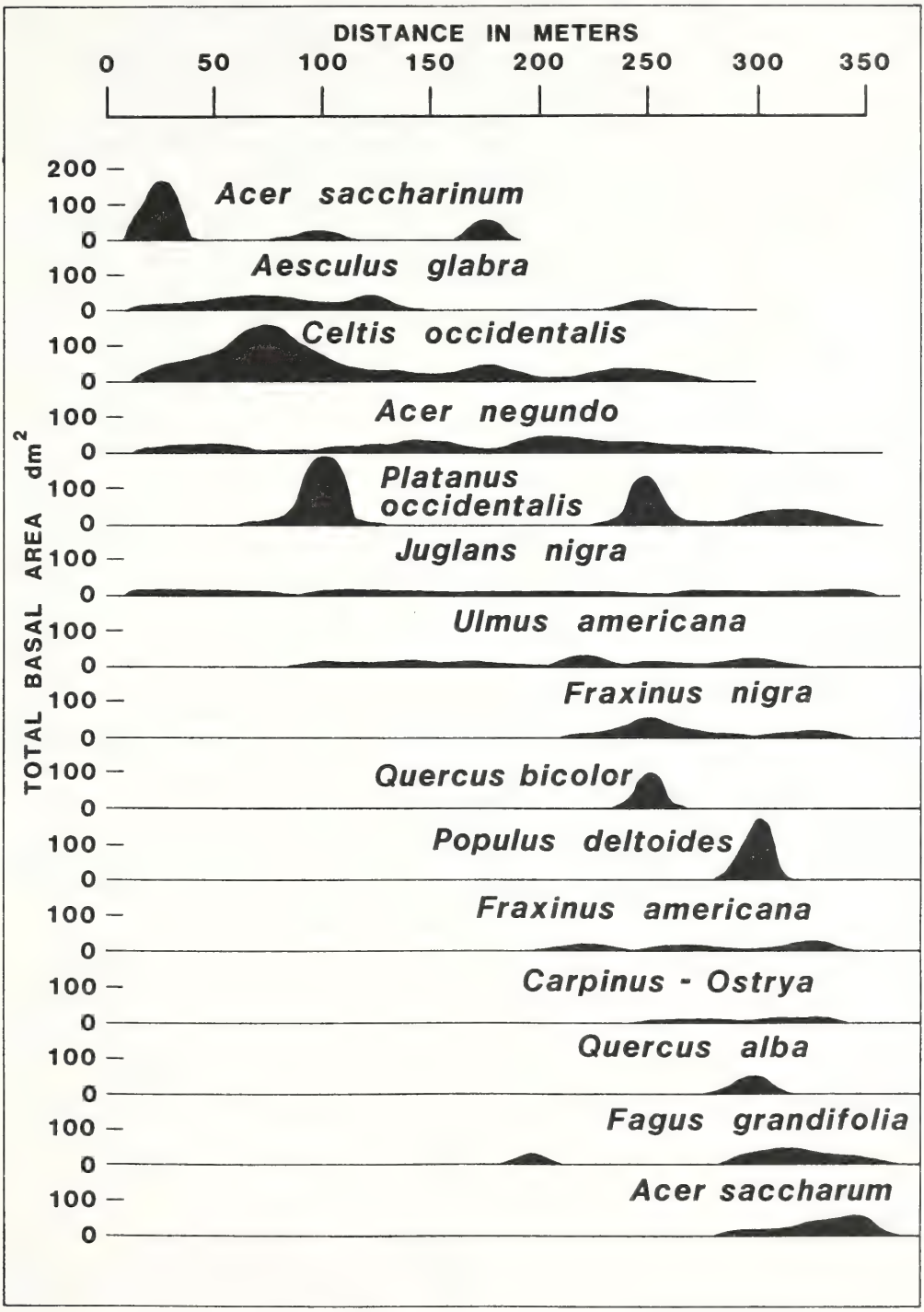

FIGURE 2. *Changes in absolute basal area values for canopy tree species along transects from the White River to the upland. Values are additive for the two transects and expressed in square decimeters.*

Discussion

Although floodplains provide relatively uniform ecological conditions over considerable geographic distance, variations in topography, soils and drainage create a mosaic of microhabitats within a given stand (Petty and Jackson, 1966) (7). Such

variability permits floodplain forest communities to assume a more fixed character than would usually be typical for an upland site with similar variations in relief. Dominance of canopy trees shifts markedly (Figure 2) in response to distance from the river, presence of depressions or low ridges and differences in soil texture. As demonstrated by Lindsey, *et al.* (1961), they are particularly well-suited for continuum analysis in response to flooding tolerance of tree species (6).

Figure 2 is a graphical representation of continuum shifts in canopy composition typical of old-growth floodplain stands. Groundlayer species have similar changes in composition and dominance along floodplain gradients (Table 2), although the relatively greater number of species causes more blurring of differences than occurs for trees. Densities are too low within the shrub layer to demonstrate much zonation within the floodplain proper, but changes are pronounced between floodplain and upland (Table 2).

Lee's (1945) study of 20 floodplain stands throughout much of the length of the White River revealed nine tree species to be major contributors to canopy cover for all stands studied (5). Seven of the nine species were common to this study. *Salix nigra* was conspicuously absent from the stand. Lee's (1945) stand near the Hamilton-Marion County line is remarkably similar to our stand in that the six most prevalent species in each study are identical, and in almost the same order of importance (5). In both cases *Aesculus glabra* assumed greater importance than usually occurs in floodplain forests.

Both Crankshaw (1964) and Qadir (1964) listed forest composition by soil types for presettlement Indiana (2,8). Their stand tables for Eel and Genesee silt loam soils list more mesophytic species at higher importance of American beech and sugar maple in presettlement floodplain forests (beech averaged 24.8% importance for the two soil types in the two studies; sugar maple averaged 9.2%). We found a single large beech and no sugar maple. White oak and tulip tree (*Liriodendron tulipifera*) were both present on presettlement floodplains, but absent today. Ohio buckeye averaged 5.5% in presettlement floodplains; almost identical to our value of 6.2%.

Undoubtedly the frequency, duration and heights of floods have been increased due to clearing the watershed for agricultural and other purposes. Silt coatings of floodplain soils during high water may also retard seedling establishment for mesophytic species. With increased pressures on watersheds of Midwestern streams, the few remaining high quality floodplain forests such as the one described here take on increased value as reference ecosystems. Our hope is that this study will improve the chances for preservation of this fine old-growth stand.

Acknowledgment

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A Floristic Survey of Acid Seep Springs in Martin and Dubois Counties, Indiana

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Introduction

A seep spring natural community is an area with a soil or peat substrate saturated by a continuous, diffuse flow of groundwater (18). Those where the substrate and the water flowing through them are acid are termed acid seep springs. Although described in surrounding states (16,11), acid seep springs have not previously been recognized in Indiana (8,12). In this state they are apparently restricted to the unglaciated region where three examples are known. One site in Monroe County which I am classifying as an acid seep spring community was known historically as a bog (13), and another acid seep springs site in Dubois County was termed a swamp and marshy woods (2). A third site was discovered in Martin County in 1982 by the author and Tom Post.

A floristic inventory was conducted at the Martin County and Dubois County acid seep spring sites in 1982 and 1983. Several species infrequently found in southern Indiana were discovered, including two currently known in the state only from the Dubois County site. The two species, *Poa paludigena* and *Carex atlantica* subsp. *capillacea*, are listed as endangered in Indiana (1).

Methods

The sites were visited at various intervals during the growing seasons of 1982 and 1983. Plant species seen were noted at the sites, although some were collected for further study and documentation. Specimens will be deposited in the Deam Herbarium at Indiana University in Bloomington. The *Carex atlantica* subsp. *capillacea* was deposited at the University of Michigan Herbarium. Nomenclature follows Gleason (4), with the exception of *Platanthera*, which follows Luer (9) and *Carex atlantica* subsp. *capillacea*, which follows Reznicek (15).

On October 13, 1983 water samples from the seep springs were tested at the sites with a portable pH meter. The samples tested were taken from a small rivulet flowing through the seep and from water collected in a ten centimeter deep depression made in the peat. Samples were also tested for total dissolved solids at a laboratory of the Indiana Geological Survey in Bloomington.

The Study Area

I am aware of three acid seep spring sites in the state. All are in unglaciated landscapes and each in a separate physiographic region of the Interior Low Plateaus Province (10,14). The Wening-Sherritt Seep Springs in Dubois County occur on the Ohio River Hills and Lowlands subsection (Wabash Lowland), the Plaster Creek Seep Springs in Martin County occur on the Mammoth Cave Plateau Subsection (Crawford Upland), and Baxter's Bog in Monroe County (now under water of Monroe Reservoir) occurred on the Norman Upland Subsection.

Baxter's Bog was studied and described in detail by Potzger (13). It occurred on an old river terrace presumably formed during the Pleistocene Epoch. He states that sediment washed from nearby uplands eventually filled small stream courses on

the terrace, thereby ponding precipitation runoff to form the bog. However, he also states, "In addition to the normal rainfall and stream-water accumulation, seepage from the old river terraces enter at several places like springs". That statement and the reported acidity (pH 5.8) and unique flora indicate the occurrence of acid seep springs, and not a bog as currently defined. It occurred in the SW ¼, Section 31, T8N, R1E.

Seepage emanates at or near the base of massive Mansfield sandstone cliffs to form the Plaster Creek Seep Springs (Figure 1). The community is mostly forested, but a portion is a wet meadow, with only a few scattered trees and shrubs. The seeps, with water having a pH range of 5.6 to 5.9, occur as a discontinuous linear strip along the lower slope and valley floor, approximately 400 meters long and ten meters wide. They occur predominantly in the SW ¼, Section 11, T2N, R4W.

The Wening-Sherritt Seep Springs occur on Negley silt loam and Bonnie silt loam in a small forested valley slightly entrenched in Pleistocene lacustrine deposits (6, 19). The seeps form a discontinuous 300 meter long, five to ten meter wide strip between the base of upland slopes and an alluvial plain. In appearance they look like small linear bogs, even to the point of quaking slightly when disturbed. Water tested yielded a pH range of 5.8 to 5.9. The seeps are located in the SW ¼, Section 3, T1S, R5W.

Plant Communities

The vegetation of acid seep springs consists of an unique assemblage of plants; at least in southern Indiana. The most conspicuous and characteristic plants are the *Osmunda* ferns, particularly *O. cinnamomea* and *O. regalis*. These ferns often dominate the seep community by forming a distinct sub-canopy. The hummocks formed from the base of thse ferns provide the only stable substrate for many species, especially mosses and liverworts. *Poa paludigena, P. autumnalis*, and several *Carex* species are found almost exclusively on these hummocks at the Wening-Sherritt site. *Sphagnum* sp. is scattered throughout the seeps, though seldom forming a large continuous mat. A vareity of sedges are found, the most characteristic being *Carex bromoides, C. crinita*, and *C. lurida. Carex debilis* and *C. atlantica* subsp. *capillacea* are common at the Wening-Sherritt site, but absent from Plaster Creek. The typical grasses are *Panicum microcarpon, Leersia oryzoides, Cinna arundinacea*, and *Glyceria striata*. Other herbs characteristic of the seep springs are *Solidago patula, S. rugosa, Aster puniceus, Impatiens biflora, Polygonum arifolium, Oxypolis rigidor*, and *Platanthera clavellata*.

Woody shrubs characteristic of the seeps include *Ilex verticillata, Aronia melanocarpa, Lindera benzoin*, and *Viburnum dentatum. Rhus vernix* and *Alnus serrulata* are common mid-canopy species of the Wening-Sherritt site. The few tree species encountered usually occur on the border and on larger hummocks of the seep springs. These include *Nyssa sylvatica, Liriodendron tulipifera, Acer rubrum, Populus heterophylla, Fraxinus pennsylvanica, Quercus bicolor, Q. michauxii*, and *Liquidambar styraciflua*.

Many fallen trees are found throughout the seeps, most probably uprooted by strong winds. Large trees are apparently too heavy to be supported by the mucky substrate and therefore uproot during a windstorm. The broken upper canopy has resulted in a relatively sunny environment in the mid and lower canopy zones, producing a lush and occasionally rank vegetative growth in places. In the wet meadow portion of Plaster Creek, dense growths of *Amphicarpa bracteata, Polygonum arifolium*, and *Leersia oryzoides* cover all but the tallest herbs by summer's end.

Results and Discussion

Although acid seep springs are quite rare in Indiana, the landforms where they occur are not (5). Given that fact, one would expect to find several examples of acid

FIGURE 1. *Photo of Plaster Creek acid seep springs showing Osmunda, Saururus,* and *Sphagnum.*

seep springs, but nowhere have they been found except for the three cited examples. Studies of the hydrology and geology of the known seeps may identify a common feature responsible for their rarity.

The cause of the acidity of the seep springs' water is not well understood. A test for dissolved solids yielded low readings (135 ppm and 65 ppm for the Wening-Sherritt and Plaster Creek sites respectively), implying that sulfates or other inorganic agents are not contributing significantly to the acidity of the water (7). Organic acids leaching from the peat, or the absence of buffering agents in the soil to neutralize precipitation, e.g. carbonates, could account for the acidity.

Ninety-three taxa were found at the Wening-Sherritt Seep Springs and one hundred and six taxa at the Plaster Creek Seep Springs (see Table 1). Many of these species are characteristic of acid seep spring communities in surrounding states, notably Illinois, Kentucky, and Missouri (11,16). Some of the species common to all or most of the seeps in the states include *Osmunda cinnamomea, O. regalis, Platanthera clavellata, Polygonum arifolium, P. sagittatum, Aronia melanocarpa, Solidago patula, S. rugosa, Panicum microcarpon, Carex lurida, C. crinita, C. bromoides, Eupatorium fistulosum, Boehmeria cylindrica*, and *Sphagnum* sp.

TABLE 1. *Vascular Flora of Two Indiana Acid Seep Springs and Environs*

Taxa	Wening-Sherritt Seep Springs	Plaster Creek Seep Springs
Aceraceae		
Acer rubrum L.	X	X
Acer saccharum Marsh.	X	
Alismaceae		
Alisma subcordatum Raf.		X
Anacardiaceae		
Rhus radicans L.	X	X
Rhus vernix L.	X	
Annonaceae		
Asimina triloba (L.) Dunal	X	
Aquifoliaceae		
Ilex verticillata (L.) Gray	X	X
Araceae		
Arisaema triphyllum (L.) Schott.		X
Balsaminaceae		
Impatiens biflora willd.	X	X
Berberidaceae		
Podophyllum peltatum	X	
Betulaceae		
Alnus serrulata (Ait.) Willd.	X	
Betula nigra L.	X	X
Carpinus caroliniana Walt.		X
Corylus americana Walt.		X
Caprifoliaceae		
Lonicera japonica Thumb.	X	
Sambucus canadensis L.	X	
Viburnum acerifolium L.		X
Viburnum dentatum L.	X	X
Viburnum prunifolium L.	X	
Caryophyllaceae		
Stellaria longifolia Muhl.	X	
Celastraceae		
Euonymus americanus L.	X	X
Euonymus atropurpureus Jacq.	X	

TABLE 1.—Continued

Taxa	Wening-Sherritt Seep Springs	Plaster Creek Seep Springs
Compositae		
Aster lateriflorus (L.) Britt.	X	
Aster puniceus L.	X	X
Aster umbellatus Mill.		X
Bidens coronata (L.) Britt.		X
Eupatorium fistulosum Barratt	X	X
Eupatorium perfoliatum L.		X
Senecio aureus L.	X	X
Solidago patula Muhl.	X	X
Solidago rugosa Mill.	X	
Convolvulaceae		
Cuscuta compacta Juss.		X
Cuscuta gronovii Willd.	X	
Cornaceae		
Cornus florida L.		X
Cornus racemosa Lam.	X	
Nyssa sylvatica Marsh.	X	X
Crassulaceae		
Penthorum sedoides L.		X
Cruciferae		
Cardamine bulbosa (Schreb.) BSP.	X	
Cyperaceae		
Carex atlantica subsp. *cappillacea* (L. H. Bailey) Reznicek	X	
Carex bromoides Schk.	X	X
Carex crinita Lam.	X	X
Carex cristatella Britt.		X
Carex debilis Michx.	X	
Carex gracillma Schmw.	X	X
Carex grayii Carey		X
Carex lacustris willd.	X	
Carex laevivaginata (Kukenth) Mackenzie	X	
Carex lupulina Muhl.		X
Carex lurida Wahl.	X	X
Carex prasina Wahl.	X	X
Carex rosea Schk.		X
Carex squarrosa L.		X
Carex tribuloides Wahl.		X
Carex typhina Michx		X
Carex vulpinoidea Michx.		X
Cyperus strigosus L.	X	
Dulichium arundinaceum (L.) Britt.	X	
Scirpus polyphyllus Vahl.	X	X
Dioscoreaceae		
Dioscorea villosa L.		X
Ebenaceae		
Diospyros virginiana L.	X	
Fagaceae		
Fagus grandifolia Ehrh.	X	X
Quercus alba L.		X
Quercus bicolor Willd.		X
Quercus michauxii Nutt.	X	
Quercus palustris Muenchh.	X	X
Quercus prinus L.		X
Quercus rubra L.	X	X
Gentianaceae		
Bartonia virginica (L.)	X	

TABLE 1.—Continued

Taxa	Wening-Sherritt Seep Springs	Plaster Creek Seep Springs
Gramineae		
Cinna arundinacea L.	X	X
Glyceria striata (Lam.) Hitche.	X	X
Leersia oryzoides(L.) Sw.	X	X
Leersia virginica Willd.	X	
Panicum clandestinum L.		X
Panicum microcarpon Muhl.	X	X
Poa autumnalis Muhl.	X	
Poa paludigena Fern. & Wieg.	X	
Hamamelidaceae		
Liquidambar styraciflua L.		X
Iridaceae		
Iris virginica L.	X	X
Juncaceae		
Juncus acuminatus Michx.		X
Juncus effusus L.	X	X
Juncus tenuis Willd.		X
Labiatae		
Prunella vulgaris L.		X
Lauraceae		
Lindera benzoin (L.)	X	X
Sassafras albidum (Nutt.) Nees.		X
Leguminosae		
Amphicarpa bracteata (L.)		X
Apios americana Medic.	X	X
Desmodium nudiflorum (L.) DC.		X
Liliaceae		
Medeola virgininana L.		X
Smilax glauca Walt.		X
Smilax rotundifolia L.		X
Lobeliaceae		
Lobelia cardinalis L.	X	X
Lycopodiaceae		
Lycopodium porophilum Lloyd & Underw.		X
Magnoliaceae		
Liriodendron tulipifera L.	X	X
Oleaceae		
Fraxinus pennsylvania Marsh.	X	X
Onagraceae		
Epilobium coloratum Biehler	X	X
Ludwigia alternifolia L.		X
Ophioglossaceae		
Botrychium virginianum (L.) Sw.	X	
Orchidaceae		
Platanthera clavellata (Michx.) Luer	X	X
Platanthera lacera (Michx.) G. Don	x	
Tipularia discolor (Pursh) Nutt.		X
Orobanchaceae		
Conopholis americana (L.) Wallr.		X
Epifagus virginiana (L.) Bart.		X
Osmundaceae		
Osmunda cinnamomea L.	X	X
Osmunda claytoniana L.		X
Osmunda regalis L.	X	X
Polemoniaceae		
Phlox glaberrima L.	X	X

TABLE 1.—Continued

Taxa	Wening-Sherritt Seep Springs	Plaster Creek Seep Springs
Polygonaceae		
Polygonum arifolium L.	X	X
Polygonum sagittatum L.		X
Polygonum virginianum L.	X	X
Polypodiaceae		
Athyrium filix-femina (L.) Roth	X	X
Dryopteris cristata (L.) Gray	X	X
Onoclea sensibilis L.		X
Thelypteris noveboracensis (L.) Niewl.	X	X
Thelypteris palustris Schott.		X
Primulaceae		
Lysimachia nummularia L.	X	
Ranunculaceae		
Caltha palustris L.	X	
Ranunculus recurvatus Poir	X	
Ranunculus hispidus Michx.		X
Rosaceae		
Agrimonia parviflora Ait		X
Aronia melanocarpa (Michx.) Ell.	X	X
Prunus serotina Ehrh.	X	X
Rosa multiflora Thumb.	X	
Rosa palustris marsh.	X	X
Spiraea alba Du Roi	X	
Rubiaceae		
Cephalanthus occidentalis L.	X	X
Galium tinctorium L.		X
Mitchella repens L.	X	X
Salicaceae		
Populus deltoides Marsh.	X	
Populus heterophylla L.		X
Populus grandidentata Michx.		X
Salix sericea Marsh.		X
Saururaceae		
Saururus cernuus L.	X	X
Saxifragaceae		
Heuchera americana L.		X
Hydrangea arborescens L.		X
Itea virginica L.	X	
Saxifraga pennsylvanica L.	X	
Scrophulariaceae		
Chelone glabra L.	X	X
Mimulus alatus Ait.		X
Scrophularia marilandica L.		X
Typhaceae		
Typha latifolia L.	X	X
Ulmaceae		
Ulmus americana L.	X	
Umbelliferae		
Cicuta maculata L.	X	X
Oxypolis rigidior(L.) C. & R.	X	X
Urticaceae		
Boehmeria cylindrica (L.) Sw.	X	X
Pilea pumila (L.) Gray		X
Violaceae		
Viola missouriensis Greene	X	
Vitaceae		
Parthenocissus quinquefolia (L.) Planch.	X	X

Plants of widely different geographic affinities can be found in Indiana acid seep springs. For instance, there are very few other areas, if any, where one can find northern species such as *Dryopteris cristata, Poa paludigena*, and *Saxifraga pennsylvanica* growing with the southern species *Itea virginica, Quercus michauxii*, and *Liquidambar styraciflua*. Generally though, most of the species are of widespread midwestern and eastern distribution.

The rarest plant occurring in the seep springs is *Poa paludigena*. Personal communication with botanists in all states of its range reveal only four known populations collected from or seen in the past fifteen years. Collected at the Wening-Sherritt Seep Springs on June 4, 1929 by Charles Deam, this species was rediscovered there in 1982 by Cloyce Hedge, Lee Casebere, and the author.

A plant common to the Wening-Sherritt Seep Springs is *Carex atlantica* subsp. *capillacea*. Known formerly as *C. howei*, this species was previously collected only once in Indiana, in Porter County on June 17, 1923 (3). *Carex howei* has been grouped with *C. mohriana, C. atlantica*, and *C. incomperta* (the latter is a plant common to southern Illinois acid seep springs) to form the *C. atlantica* complex as defined by Reznicek (15).

Although the two seep spring sites are relatively undisturbed and efforts are underway to protect them, they are not without potential threats. The hydrologic system is the critical feature of the seeps and any alteration of it could have adverse consequences. Other threats include herbicide drift from nearby agricultural activities and utility line right-of-way vegetation control, groundwater contamination, drainage changes, and siltation from run-off of nearby cultivated fields. A few exotic species are present, notably *Lonicera japonica* and *Rosa multiflora*. Currently they are infrequent and not a serious problem. A dense stand of *Typha latifolia* occurs under a utility line right-of-way, but has not spread into the adjacent seeps.

Attempts are being made by the Indiana Division of Nature Preserves to locate more seep spring communities. Recent efforts have been unsuccessful, due primarily to the apparent rarity of the community and difficulty in systematically identifying potential sites from aerial photos, maps, and other materials.

Acknowledgments

Several individuals to whom I am grateful contributed to this study. I thank Jim Aldrich, John Bacone, Ted Cable, Lee Casebere, Cloyce Hedge, Mike Lodato, Tom Post, Helene Starcs, and Bill Weeks for field assistance; Dr. Henry Gray and Ed Hartke for geologic and hydrologic information and field assistance; Lewis Johnson for herbarium assistance; Dr. A. A. Reznicek for the vertification of *Carex atlantica* subsp. *capillacea*; Floyd Swink for verification of *Poa paludigena*; Paul Nelson for information on Missouri acid seep springs; the Wenings for providing access to study their seeps; and Brian Abrell, Tammy Carrigg, and my wife Barbara for technical assistance.

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Indiana Plant Distribution Records XXIII

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The genera are listed in the order of their appearance in Deam's *Flora of Indiana* (1940). Species are listed alphabetically within each genus. They are followed by the names of the counties in which they were collected. The nomenclature follows that of Gleason and Cronquist (1963). Voucher specimens are in the herbarium at Indiana University.

These specimens were collected by M. Brunner, D. Burgette, J. W. Ewing, C. B. Heiser, Jr., C. B. Hersis, Jr., D. Inman, L. Johnson, R. Johnson, S. R. Kephart, M. Kowalski, E. Lozano, K. McGrary, A. Mergens, P. Munson, W. Purepong, H. Wilson, A. B. Wood, and G. Yatskievych.

Taxonomic Entities

Vittaria lineata, Martin, Perry. *Equisetum hyemale* var. *affine*, Bartholomew. *Lycopodium selago* var. *patens*, Owen. *Potamogeton nodosus*, Monroe. *Sagittaria latifolia*, Brown. *S. rigida*, Brown. *Bromus inermis*, Morgan. *Hystrix patula*, Morgan. *Hordeum jubatum*, Greene. *Phalaris arundinacea*, Morgan, *Paspalum pubiflorum* var. *glabrum*, Greene. *Erianthus alopecuroides*, Crawford. *Sorghum halapense*, Greene.

Sciprus atrovirens, Morgan. *S. torreyi*, Monroe. *Eleocharis plaustris*, Monroe. *Carex davisii*, Morgan. *C. granularis*, Morgan. *Commelina communis*, Morgan. *Juncus torreyi*, Monroe. *Trillium recurvatum*, Morgan. *Corallorhiza odontorhiza*, Fountain.

Rumex acetosella, Morgan. *Polygonum caespitosum*, Brown. *P. cuspidatum*, Monroe. *P. punctatum*, Morgan. *Chenopodium ambrosioides*, Dearborn. *Dianthus armeria*, Morgan. *Nelumbo lutea*, Brown. *Alliaria officinalis*, Monroe, Morgan. *Potentilla recta*, Morgan. *Medicago sativa*, Morgan. *Vicia villosa*, Morgan. *Lathyrus latifolius*, Monroe. *Lotus corniculatus*, Monroe. *Pueraria lobata*, Brown, Morgan. *Hibisus moscheutos*, Monroe. *Hypericum perforatum*, Morgan.

Osmorhiza longistylis, Morgan. *Monotropa hypopitys* var. *rubra*, Fountain. *M. uniflora*, Martin. *Anagallis arvensis*, Monroe, *Asclepias verticillata*, Grant, Huntington, Madison, Wells. *Convolvulus sepium*, Spencer. *Ipomoea pandurata*, Greene. *Mertensia virginica*, Morgan. *Agastache nepetoides*, Morgan. *Glecoma hederacea*, Spencer. *Lamium amplexicaule*, Morgan.

Solanum nigrum, Greene. *Verbascum blattaria*, Morgan. *Chelone obliqua*, Martin. *Galium trifidum*, Monroe. *Lonicera japonica*, Morgan. *Valeriana pauciflora*, Morgan. *Elephantopus carolinianus*, Morgan. *Eupatorium coelestinum*, Brown. *Aster novae-angliae*, Morgan. *A. pilosus*, Spencer. *A. simplex*, Monroe. *Erigeron annuus*, Morgan. *E. philadelphicus*, Morgan. *Polymnia canadensis*, Morgan. *Senecio glabellus*, Monroe. *Centaurea maculosa*, Monroe. *Tragopogon dubius*, Morgan.

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New Vascular Plant Distribution Records for Tippecanoe County, Indiana

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Tippecanoe County, Indiana, lies on the southern edge of the "prairie peninsula" in northwest Indiana (6). To the south and southwest of the prairie openings, the steady-state presettlement vegetation was oak-hickory forest (1,4). On some north- and east-facing slopes in the county, a beech-maple association occurs. Thus, the Lafayette area is at the junction of three floristic provinces and, as a result, has a varied flora.

In 1980, I began a catalogue of the vascular plants of Tippecanoe County for use in teaching botany courses at Purdue University. Contrary to the theory that plant distribution records are a function of the distribution of plant collectors (5), there were surprisingly numerous omissions from the resulting checklist for the home county of Indiana's land grant university. Seventy-one new taxa (Table 1) are reported here for Tippecanoe County. Ten other species were listed recently by McCain and Hennen (5).

TABLE 1. *List of new reports of vascular plants for Tippecanoe County, Indiana.*

PTERIDOPHYTES

AZOLLACEAE (new family record): *Azolla caroliniana* Willd.

LYCOPODIACEAE (new family record): *Lycopodium digitatum* A. Braun.

OPHIOGLOSSACEAE: *Botrychium dissectum* Spreng. var. *obliquum* (Muhl.) Clute*, *Ophioglossum vulgatum* L.

OSMUNDACEAE (new family record): *Osmunda cinnamomea* L.

MONOCOTYLEDONS

CYPERACEAE: *Carex albursina* Sheldon.

HYDROCHARITACEAE (new family record): *Elodea canadensis* L.C. Rich.

LEMNACEAE: *Lemna trisulca* L.*

LILIACEAE: *Hemerocallis fulva* (L.) L., *Ornithogalum umbellatum* L., *Trillium recurvatum* Beck. f. *luteum* Clute*.

NAJADACEAE (new family record): *Najas flexilis* (Willd.) Rostk. & Schmidt.

ORCHIDACEAE: *Liparis loeselii* (L.) L.C. Rich., *Spiranthes lacera* (Raf.) Raf. var. *gracilis* (Bigelow) Luer.

POACEAE: *Aristida oligantha* Michx., *Chloris verticillata* Nutt., *Cynodon dactylon* (L.) Pers., *Koeleria cristata* (L.) Pers., *Lolium perenne* L., *Setaria faberi* Herrn.

POTAMOGETONACEAE (new family record): *Potamogeton crispus* L., *P. foliosus* Raf., *P. nodosus* Poir.

SPARGANIACEAE: *Sparganium chlorocarpum* Rydb.

DICOTYLEDONS

APIACEAE: *Aegopodruim podagraria* L., *Heracleum lanatum* Michix., *Osmorhiza longistylis* (Torr.) DC., *Torilis japonica* (Houtt.) DC.

APOCYNACEAE: *Vinca minor* L.

ASTERACEAE: *Carduus nutans* L., *Cichorium intybus* L., *Galinsoga quadriradiata* Ruiz & Pavon, *Lapsana communis* L., *Silphium laciniatum* L.

BRASSICACEAE: *Alliaria petiolata* (Bieb.) Cavara & Grande, *Cardamine parviflora* L. spp. *parviflora* var. *arenicola* (Britt.) O.E. Schulz, *Hesperis matronalis* L., *Lepidium campestre* (L.) R. Br., *Rorippa sylvestris* (L.) Bess., *Sinapsis arvensis* L.

TABLE 1.—Continued

CERATOPHYLLACEAE (new family record): *Ceratophyllum demersum* L.

CHENOPODIACEAE: *Kochia scoparia* (L.) Schrad.

CRASSULACEAE (new family record): *Sedum ternatum* Michx.

ERICACEAE: *Chimaphila maculata* (L.) Pursh., *Monotropa hypopithys* L.

FABACEAE: *Coronilla varia* L., *Lotus corniculatus* L., *Trifolium hybridum* L.

GENTIANACEAE: *Frasera caroliniensis* Walt.

HALORAGIDACEAE (new family record): *Myriophyllum exalbescens* Fern.

HYDROPHYLLACEAE: *Hydrophyllum canadense* L., *Phacelia purshii* Buckl.

LAMIACEAE: *Collinsonia canadensis* L.

LENTIBULARIACEAE (new family record): *Utricularia gibba* L.

MALVACEAE: *Malva rotundifolia* L.

MORACEAE: *Maclura pomifera* (Raf.) Schneid.

NYMPHAEACEAE (new family record): *Brasenia schreberi* J. F. Gmel., *Nelumbo lutea* (Willd.) Pers., *Nuphar luteum* (L.) Sibthorp & Sm. ssp. *variegatum* (Dur.) E. O. Beal.

POLYGALACEAE: *Polygala sanguinea* L.

ROSACEAE: *Rosa multiflora* Thunb. ex Murr.

RUBIACEAE: *Mitchella repens* L.

SALICACEAE: *Salix humilis* Marsh.

SCROPHULARIACEAE: *Veronica catenata* Pennell.

SOLANACEAE: *Solanum dulcamara* L.

VIOLACEAE: *Viola incognita* Brainerd, *V. missouriensis* Greene, *V. obliqua* Hill, *V. papilionaceae* Pursh. f. *albiflora* Grover*, *V. triloba* Schw.

*taxa not accepted as distinct by Crovello *et al.* (2) but which were considered separable in this study.

A majority of these taxa fall into one of two categories: aquatics or weeds. Other than Cyperaceae, not many aquatic plants have been reported until now for this county. Eight families of aquatics are listed for the first time: Azollaceae, Ceratophyllaceae, Haloragidaceae, Hydrocharitaceae, Lentibulariaceae, Najadaceae, Nymphaeaceae, and Potamogetonaceae. A notable species on the list is *Nelumbo lutea*, the American water-lotus. Although it was probably introduced, it has become fully established at the Purdue Wildlife Area.

The other large category, weedy annuals and perennials, includes some species evidently of recent arrival so that they could not have been cited in previous reports. These include *Rosa multiflora, Carduus nutans*, and *Lapsana communis*. Three species are adventives along an old railroad track south of West Lafayette: *Aristida oligantha, Chloris verticillata*, and *Kochia scoparia*. Other unreported species must have been assumed as reported by most researchers but, surprisingly, no published reports have been located for such species as *Setaria faberi, Hemerocallis fulva, Lepidium campestre, Solanum dulcamara*, or *Cichorium intybus*. Introduced species that have become fully established include perennial rye, creeping myrtle, and the three legumes in Table 1.

The Tippecanoe County vascular plant flora list now includes 1040 species, plus 55 additional subspecific taxa (for 1094 total), in 485 genera, representing 120 families. Deam (3) tallied only 829 taxa in the county, so the species collated from this report and other literature (McCain, unpublished manuscript) represent an increase of 266 taxa over Deam's list. The Lycopodiaceae and Osmundaceae are listed for the first time. The citation for the original report and date of the most recent collection are

on file for each species, as well as estimates of abundance or rarity. Nomenclature follows Crovello *et al.* (2).

Acknowledgments

Grateful acknowledgement for assistance in compiling this list or in obtaining voucher specimens to support these new reports is given to Dr. Arthur T. Guard, Purdue professor emeritus, who extracted many of the reports from Deam's manual (3), Dr. Carole A. Lembi of Purdue, Susan Ulrich of rural western Tippecanoe County, and Dr. Delano Z. Arvin, M.D., of Buck Creek, who helped me find several of the new species, and to the students of Botany 507, 1982 summer session at Purdue: John Matthew Beatty, Hans Landel, Stewart Sherrick, and Mark Venzke. Voucher specimens have been deposited in the Kriebel Herbarium, Department of Biological Sciences, Purdue University. Journal paper number 9679 and the Purdue University Agricultural Experiment Station.

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Additions to the Flora of Spencer County, Indiana

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A florstic study was made of the vascular plant populations of an industrial site located two miles northeast of Rockport in extreme southern Spencer County, Indiana. This study resulted in the collected of 92 species of vascular plants not previously reported by Deam (1940). Records published subsequent to the "Flora of Indiana" include an additional 93 speicies. (Deam et al 1941, Ellis 1961, Mergen 1972, Kays and Humbles 1974). Including the species reported here, the vascular flora recorded for the county totals 667 species, including 16 ferns or fern allies, 1 gymnosperm, 472 dicots, and 180 monocots.

Of the 92 species of vascular plants, all but two species were previously reported for Indiana. These plants, *Anoda cristata* (L.) Schlect and *Gerardia fasiculata* Ell., are new to Indiana. A significant distribution record is reported for *Orobanche ludoviciana* Nutt. This plant was previously known from Gibson, Knox, and Jefferson Counties.

In the following list of plants each species is followed by a brief note on its habitat, the collector's name and the collection number. The nomenclature follows Fernald (1950). Voucher specimens of all species were deposited in the Stover Herbarium of Eastern Illinois University and the Herbarium of WAPORA, Inc., 6900 Wisconsin Avenue, Washington, D.C.

Acknowledgments

An appreciation is extended to Dr. John Ebinger for verification of selected specimens and for reviewing the manuscript. A special appreciation is extended to American Electric Power Service Corporation for funding the study.

Annotated List of Species

GYMNOSPERMAE

Cupressaceae
Juniperus virginiana L. Fallow field. W. McClain 926.

DICOTYLEDONEAE

Apocynaceae
Apocynum cannabinum L. Fallow field. W. McClain 1260.

Asclepiadaceae
Asclepias hirtella (Pennell) Woodson, Fallow field. W. McClain 1504.

Chenopodiaceae
Chenopodium album L. Fallow field. W. McClain 1674.

Compositae
Artemisia annua L. Cultivated field. W. McClain 997.
Aster pilosus Willd. Fallow field. W. McClain 1665.
Aster vimineus Lam. Fallow field. W. McClain 1479.
Bidens frondosa L. Cultivated field. W. McClain 1671.
Boltonia asteroides (L.) L'Her. Fallow field. W. McClain 1498.
Chrysanthemum leucanthemum L. Fallow field. W. McClain 1273.

Cirsium vulgare (Savi)) Tenore, Fallow field. W. McClain 935.
Conyza canadensis L. Fallow field. W. McClain 1012.
Helianthus hirsutus Raf. Floodplain. W. McClain 1672.
Solidago hirtella Fallow field. W. McClain 1502.
Veronica missurica Raf. Fallow field. W. McClain 1497.
Xanthium strumarium L. Floodplain. W. McClain 1057.

Convolvulaceae
Ipomea pandurata (L.) G.F.W. Mey. Fallow field. W. McClain 1426.

Cornaceae
Cornus racemosa Lam. Roadside W. McClain 1336.

Umbelliferae
Cicuta maculata L. Immature forest. W. McClain 1289.

Leguminosae
Amorpha fruticosa L. Roadside. W. McClain 1062.
Amphicarpa bracteata (L.) Fern. Floodplain. W. McClain 942.
Desmondium glabellum (Michx.) DC. Immature forest. W. McClain 1527.
Lespedeza cuneata (Dum-Cours) G. Don. Roadside. W. McClain 1476.
Lespedeza stipulacea Maxim. Fallow field. W. McClain 1507.
Robinia pseudoacacia L. Roadside. W. McClain 1308.
Strophostyles helvola (L.) Britt. Floodplain. W. McClain 1528.

Lemnaceae
Lemna minor L. Pond. W. McClain 1068.

Loranthaceae
Phoradendrom flavescens (Parsh) Nutt. Parasitic on blackgum. W. McClain 1067.

Lythraceae
Rotala ramosior (L.) Koehne. Floodplain. W. McClain 1250.

Malvaceae
Anoda cristata (L.) Schlect. Cultivated field. W. McClain 1670.
Hisbiscus moscheutos L. Roadside ditch. W. McClain 1326.

Moraceae
Maclura pomifera (Raf.) Schneid. Roadside. W. McClain 1551.
Morus tatarica L. Roadside W. McClain 1326.

Onagraceae
Jussiaea repens L. Floodplain. W. McClain 1005.
Oenothera biennis L. Floodplain. W. McClain 1524.

Orobanchaceae
Orobanche ludoviciana Nutt. Parasitic on *Ambrosia trifida*. W. McClain 1534

Oxalidaceae
Oxalis dillenii Jacq. Fallow field. W. McClain 1212.
Oxalis stricta L. Immature woods. W. McClain 862.

Passifloraceae
Passiflora lutea L. Immature woods. W. McClain 1552.

Polygonaceae
Polygonum aviculare L. Roadside. W. McClain 1344.
Polygonum coccineum Muhl. Roadside. W. McClain 1478.
Polygonum cuspidatum Sieb & Zucc. Roadside. W. McClain 490.
Polygonum hydropiper L. Fallow field. W. McClain 1659.
Polygonum hydropiperoides Michx. Immature forest. W. McClain 1044.
Polygonum lapthifolium L. Floodplain. W. McClain 1546.
Polygonum persicaria L. Roadside. W. McClain 1325.

Rosaceae
Amaanchier arborea (Michx.) Fern. Immature forest. W. McClain 1342.
Rosa multiflora Thunb. Fallow field. W. McClain 928.

Scrophulariaceae
Gerardia fasiculata Ell. Edge of pond. W. McClain 1513.
Gratiola virginiana L. Edge of pond. W. McClain 1341.

Solanaceae
Datura stramonium L. Cultivated field. W. McClain 1058.
Urtica dioica L. Floodplain. W. McClain 1238.

Verbenaceae
Verbena urticifolia L. Roadside. W. McClain 1303.

Violaceae
Viola lanceolata L. Fallow field. W. McClain 1264.

Vitaceae
Vitis aestivalis Michx. Floodplain. W. McClain 1327.

MONOCOTYLEDONEAE

Alismaceae
Sagittaria latifolia Willd. Edge of pond. W. McClain 1243.

Cyperaceae
Carex alata T. & G. Edge of pond. W. McClain 1232.
Carex cephalophora Muhl. Fallow field. W. McClain 1262.
Carex cristatella Britt. Immature forest. W. McClain 1298.
Cyperus densicaespitosus (Matt.F.) Kukenth. Roadside ditch. W. McClain 1278.
Cyperus erythrorhizos Mohl. Fallow field. W. McClain 1490.
Cyperus ferruginescens Boeck. Roadside. W. McClain 1530.
Cyperus filiculmis Vahl. Fallow field. W. McClain 1493.
Cyperus strigosus L. Roadside. W. McClain 1311.

Graminae
Agrostis alba L. Fallow field. W. McClain 1275.
Cynodon dactylon (L.) Pers. Fallow field. W. McClain 1065.
Phragmites communis Trin. Roadside. W. McClain 1475.
Setaria faberii Herm. Fallow field. W. McClain 1484.
Setaria glauca (L.) Beauv. Fallow field. H. Parker 667.
Leptochloa filiformis (Lam.) Beauv. floodplain. W. McClain 1020.
Panicum sphaerocarpon Ell. Fallow field. W. McClain 1401.

Iridaceae
Iris brevicaulis Raf. Ditch. W. McClain 1318.

Juncaceae
Juncus biflorus Ell. Edge of pond. W. McClain 1267.
Juncus effusus L. Edge of pond. W. McClain 1231.
Juncus tenuis Willd. Edge of pond. W. McClain 1437.

Lilliacee
Allium vineale L. Roadside. W. McClain 1272.
Hemerocallis fulva L. Roadside. W. McClain 1307.

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Additions to the Flora of Sullivan County, Indiana

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During the summers of 1973, 1974 and 1975, the author conducted a floristic study of the vascular plant populations on a 5000 acre industrial site located west of Fairbanks in northwestern Sullivan County, Indiana. This study resulted in the collection of 188 species of vascular plants, including 3 ferns and fern allies, 1 gymnosperm, 55 monocots, and 129 dicots, not previously reported by Deam (1940). Records published subsequent to the "Flora of Indiana" include only an additional 14 species (Deam et al. 1940a, 1940b, 1944, 1945, 1949; Potzger and Starcs 1954). Including the species reported here, the vascular flora recorded for the county totals 721 species; 15 ferns and fern allies, 1 gymnosperm, 201 monocots and 504 dicots.

Of the 188 species reported in this paper, all but one have been previously recorded for Indiana. New stations are reported for the relatively uncommon *Liparis loselii* and *Spiranthes ovalis*. The collection of *Juncus secundus* (Ebinger, 13039) represents the second known Indiana station for this plant and *Naias minor*, an Asiatic species, is new to the state.

In the following list of plants, each species is followed by a brief note concerning its habitat, the collectors name and the collection number. The nomenclature for all species follows Fernald (1950). Voucher specimens were deposited in the Stover Herbarium of Eastern Illinois University (EIU) and the Herbarium of WAPORA, Inc. 6900 Wisconsin Avenue, Washington, D.C.

Acknowledgments

An appreciation is extended to Dr. John Ebinger for verification of selected specimens and for reviewing the manuscript. A special appreciation is extended to American Electric Power Service Corporation for funding the study.

Annotated List of Species

FERNS AND FERN ALLIES

Equisetaceae
Equisetum arvense L. Marsh. W. McClain 1106.

Ophioglossaceae
Ophioglossum vulgatum L. Immature woods. W. McClain 1129.

Polypodiaceae
Addiantum pedatum L. Mature woods. J. Ebinger 12559.

Cupressaceae
Juniperus virginiana L. Roadside. J. Ebinger 12599.

DICOTYLEDONEAE

Aristolochiaceae
Asarum acuminatum (Ashe) Bickn. Mature woods. J. Ebinger 12549.

Aizoaceae
Mollugo verticillata L. Wabash River floodplain. W. McClain 586.

Anacardiaceae
Rhus glabra L. Roadside. J. Ebinger 13001.
Rhus radicans L. Fallow field. W. Pichon 236.

Apocynaceae
Apocynum cannabinum L. Roadside. W. McClain 453.

Araliaceae
Panax quinquefolius L. Mature woods. W. McClain 546.

Asclepiadaceae
Asclepias purpurascens L. Roadside. W. McClain 1304.
Asclepias syriaca L. Roadside. W. Pichon 504.

Balsaminaceae
Impatiens biflora Walt. Marsh. W. Pichon 498.

Betulaceae
Carpinus caroliniana Walt. Mature woods. J. Ebinger 12608.

Callitrichaceae
Callitriche terrestris Raf. Cultivated field. J. Ebinger 12548.

Campanulaceae
Specularia perfoliata (L.) A.D.C. Fallow field. J. Ebinger 12927.

Caprifoliaceae
Lonicera japonica Thunb. Roadside. W. Pichon 509.
Sambucus canadensis L. Roadside. W. McClain 467.

Caryophyllaceae
Cerastium nutans Raf. Cultivated field. J. Ebinger 12527.
Cerastium viscosum L. Fallow field. J. Ebinger 12519.
Cerastium vulgatum L. Cultivated field. J. Ebinger 12528.
Dianthus armeria L. Fallow field. J. Ebinger 13012.
Lychnis alba mill. Roadside. J. Ebinger 12602.
Sagina decumbens (Ell.) T. & G. Fallow field. W. McClain 1162.
Silene virginica L. Mature woods. W. McClain 1192.
Stellaria media (L.) Cyrillo. Fallow field. W. McClain 1139.

Chenopodiaceae
Atriplex hastata (L.) Gray. Fallow field. W. McClain 539.

Compositae
Antennaria plantaginifolia (L.) Hook. Edge of woods. W. McClain 1165.
Aster shortii Lindl. Immature woods. W. McClain 673.
Aster simplex Willd. Wabash River floodplain. W. McClain 681.
Bidens polylepsis Roadside. W. McClain 561.
Chrysanthemum leucanthemum L. Roadside. W. Pichon 271.
Cichorium intybus L. Roadside. J. Ebinger 13041.
Cirsium discolor (Muhl.) Spreng. Roadside. W. McClain 456.
Helianthus decapetalus L. Immature woods. W. McClain 537.
Prenanthes alba L. Immature woods. W. McClain 699.
Pyrrhopappus carolinianus (Walt) D.C. Roadside. W. McClain 1013.
Senecio aureus L. Fallow field. W. McClain 1120.
Senecio pauperculus Michx. Cultivated field. J. Ebinger 12564.
Solidago hirtella (Greene) Bush. W. McClain 796.
Taraxacum officinale Weber. Fallow field. W. McClain 1117.
Verbesina alternifolia (L.) Britt. Fallow field. W. McClain 475.
Xanthium italicum Moretti. Wabash River floodplain. W. McClain 458.

Convolvulaceae
Convolvulus arvensis L. Roadside. W. McClain 668.
Ipomea pandurata (L.) G.F. Mey. Roadside. W. McClain 458.

Cornaceae
Cornus drummondii Meyer. Roadside. W. McClain 540.

Cruciferae
Arabidopsis thaliana (L.) Heynh. Immature woods. W. McClain 1133.
Barbarea vulgaris R. Br. Fallow field. W. McClain. 1119.
Brassica nigra (L.) Koch. Fallow field. J. Ebinger 12999.
Capsella bursa-pastoris (L.) Medic. Fallow field. W. McClain 1137.
Descuriania brachycarpa (Richards) Fern. Cultivated field. W. Pichon 66.
Draba verna L. Fallow field. W. McClain 1069.
Iodanthus pinnatifidus (Michx.) Steud. Fallow field. W. McClain 1198.

Sisymbrium officinale (L.) Scop. Fallow field. J. Ebinger 12490.
Thalaspi arvense L. Fallow field. W. McClain 1141.

Hydrophyllaceae
Hydrophyllum appendiculatum Michx. Mature woods. J. Ebinger 12566.
Phacelia bipinnatifida Michx. Roadside. J. Ebinger 12565.

Hypericaceae
Hypericum sphaerocarpum Michx. Roadside. W. McClain 672.

Juglandaceae
Juglans nigra L. Roadside. J. Ebinger 12970.

Labiatae
Lamium amplexicaule L. Fallow field. W. McClain 1138.
Leonurus cardiaca L. Immature woods. J. Ebinger 12976.
Mentha piperita L. Marsh. W. McClain 578.
Monarda bradburiana Beck. Immature woods. W. McClain 251.
Stachys tenuifolia Roadside. J. Ebinger 12977.
Stachys tenuifolia Willd. Wabash River floodplain. W. McClain 584.

Leguminosae
Cassia marilandica L. Fencerow. W. McClain 719.
Coronilla varia L. Roadside. W. McClain 645.
Gymnocladus dioca (L.) K. Koch. Roadside. W. McClain 563.
Lespedeza cuneata (Dum-Cours) G. Don. Roadside. W. McClain 628.
Lespedeza stipulacea Maxim. Fallow field. W. McClain 694.
Melilotus alba Desr. Roadside. W. McClain 461.
Melilotus officinalis (L.) Lam. Roadside. W. McClain 1313.
Robinia pseudoacacia L. Roadside. J. Ebinger 12972.
Trifolium hybridum L. Fallow field. W. McClain 177.
Trifolium procumbens L. Fallow field. W. McClain 1173.
Vicia villosa Koth. Roadside. J. Ebinger 12978.

Magnoliaceae
Liriodendron tulipifera L. Mature forest. H. Parker 278.

Malvaceae
Abutilion theophrasti Medic. Roadside. W. McClain 636.
Malva neglecta Wallr. Fallow field. J. Ebinger 12629.

Moraceae
Morus rubra L. Mature woods. J. Ebinger 12619.

Onagraceae
Circaea latifolia Hill. Immature woods. J. Ebinger 12935.
Oenothera biennis L. Roadside. W. McClain 512.
Oenothera laciniata Hill. Fallow field. W. McClain 1196.

Orobanchaceae
Epifagus virginiana (L.) Bart. Mature woods. W. McClain 734.

Oxalidaceae
Oxalis dillenii Jacq. Fallow field. W. McClain 1161.

Phytolaccaceae
Phytolacca americana L. Fallow field. W. McClain 224.

Plantaginaceae
Plantago rugelii Dcne. Fallow field. W. McClain 517.

Primulaceae
Anagallis arvensis L. Fallow field. W. McClain 245.
Centunculus minimum L. Cultivated field. J. Ebinger 13040.
Samolus parviflorus Raf. Floodplain. W. McClain 685.

Polygonaceae
Polygonum aviculare L. Floodplain. W. McClain 1344.
Polygonum cuspidatum Sieb & Zucc. Roadside. W. McClain 480.
Polygonum hydropiperoides Michx. Moist woods. W. McClain 1044.
Polygonum persicaria L. Fallow field. J. Ebinger 13008.
Polygonum scandens L. Roadside. W. McClain 532.

Ranunculaceae
Hepatica acutiloba DC Mature woods. W. McClain 1088.
Isopyrum biternatum (Raf.) T & G Mature woods. H. Parker 10.
Myosurus minimus L. Cultivated field. W. McClain 1136.
Ranaculus recurvatus Poir. Mature woods. J. Ebinger 12506.
Ranunculus septentrionalis Poir. Mature woods. J. Ebinger 12625.

Rosaceae
Agrimonia pubescens Wallr. Immature woods. W. McClain 443.
Agrimonia gryposepala Wallr. Immature woods. W. McClain 545.
Gillenia stipulata (Muhl.) Baill. Immature woods. W. McClain 254.
Potentilla norvegica L. Fallow field. J. Ebinger 13012.
Potentilla recta L. Fallow field. J. Ebinger 12979.
Prunus serotina Ehrh. Roadside. W. McClain 276.
Rubus ostryifolius Rydb. Roadside. W. McClain 1317.
Rubus allegheniensis Porter. Fallow field. J. Ebinger 12511.
Rubus flagellaris Willd. Immature forest. J. Ebinger 12476.
Rubus occidentalis L. Immature forest. J. Ebinger 12477.

Rubiaceae
Galium aparine L. Mature woods. J. Ebinger 12520.
Galium circaezans Michx. Immature woods. W. McClain 253.
Galium concinnum T. & G. Mature woods. J. Ebinger 12946.
Houstonia lanceolata (Poir) Britt. Roadside. J. Ebinger 12926.

Rutaceae
Ptelea trifoliata L. Mature woods. W. McClain 1210.

Salicaceae
Populus grandidentata Michx. Immature woods. J. Ebinger 13046.

Scrophulariaceae
Chelone obliqua L. Roadside. W. McClain 553.
Collinsia verna Nutt. Mature woods. W. McClain 26.
Leucospora multifida (Michx.) Nutt. Wabash River floodplain. W. McClain 684.
Penstemon hirsutus (L.) Willd. Fallow field. W. McClain 243.
Veronica arvensis L. Fallow field. W. McClain 1146.

Solonaceae
Physalis subglabrata Mack & Bush. Roadside. McClain 928.
Solanum carolinense L. Fallow field. W. McClain 511.

Tiliaceae
Tilia americana L. Mature woods. W. McClain 1209.

Ulmaceae
Celtis occidentalis L. Roadside. J. Ebinger 13004.
Ulmus pumila (Muhl.) Pursh. Roadside. W. McClain 722.

Umbelliferae
Erigenia bulbosa (Michz.) Nutt. Mature woods. W. McClain 1085.
Conium maculatum L. Roadside. J. Ebinger 12923.
Daucus carota L. Roadside W. McClain 270.
Osmorhiza claytonii (Michx.) Clarke. Mature woods. J. Ebinger 12524.
Pastinaac sativa L. Roadside. J. Ebinger 13042.
Sanicula gregaria Bickn. Fencerow. J. Ebinger 12598.
Sanicula canadensis L. Floodplain. J. Ebinger 12939.

Urticaceae
Urtica gracilis Ait. Fioodplain. J. Ebinger 12996.

MONOCOTYLEDONEAE

Araceae
Acorus calamus L. Marsh. W. McClain 1163.
Arisaema triphyllum (L.) Schott. Mature woods. H. Parker 11.

Commelinaceae
Commelina communis L. Roadside. J. Ebinger 12930.
Tradescantia subaspera Ker. Mature woods. J. Ebinger 12960.
Tradescantia virginica L. Mature woods. W. McClain 1166.

Cyperaceae

Carex careyana Torr. Mature woods. J. Ebinger 12626.
Carex annectens Birhn. Floodplain. J. Ebinger 12488.
Carex convoluta Mack. Fallow field. W. McClain 1168.
Carex gracilescens Steud. Mature forest. J. Ebinger 12522.
Carex grisea Wahl. Mature forest. J. Ebinger 12571.
Carex grisea Wahl. Roadside. J. Ebinger 12956.
Carex laxiflora Lam. Immature woods. W. McClain 1172.
Carex oligocarpa Schk. Mature woods. J. Ebinger 12500.
Carex plantaginea Lam. Immature woods. W. Pichon 48.
Carex sparganiodes Muhl. Fallow field. J. Ebinger 12572.
Carex swanii (Fern.) Mack. Fallow field. W. McClain 1191.
Carex vulpinoidea Michx. Fallow field. H. Parker 230.
Scirpus lineatus Michx. Roadside. J. Ebinger 12950.

Dioscoreaceae

Dioscorea quaternata (Walt.) Gmel. Immature woods. W. McClain 430.

Graminae

Bromus latiglumis (Shear) Hitch. Mature forest. W. McClain 674.
Bromus tectorum L. Fallow field. W. McClain 1207.
Diarrhena americana Beauv. Mature woods. J. Ebinger 12959.
Elymus villosus Muhl. Immature woods. J. Ebinger 12942.
Eragrostis capillaris (L.) Nees. Roadside. W. McClain 602.
Festuca elatior L. Fallow field. W. McClain 188.
Festuca octoflora Walt. Immature woods. W. McClain 1185.
Muhlenbergia frondosa (Poir) Fern. Roadside. W. McClain 486.
Panicum dichotomum L. Fallow field. J. Ebinger 12944.
Panicum latifolium L. Roadside. W. McClain 671.
Panicum virgatum L. Roadside. W. McClain 639.
Paspalum ciliatifolium Michx. Fallow field. W. McClain 608.
Paspalum publiflorum Rupr. Roadside. W. McClain 528.
Phalaris arundinacea L. Fallow field. J. Ebinger 13010.
Poa chapmaniana Scribn. Roadside. J. Ebinger 12968.
Poa sylvestris A. Gray. Mature forest. J. Ebinger 12567.
Spartina pectinata Link. Ditch. W. McClain 489.
Sphenopholis obtusata (Michx) Scribn. Fallow field. W. McClain 1182.

Juncaceae

Juncus interior Wieg. Fallow field. J. Ebinger 12982.
Juncus secundus Beauv. Cultivated field. J. Ebinger 13039.
Juncus tenuis Willd. Fallow field. W. McClain 1265.
Juncus torreyi Coville. Roadside. W. McClain 451.
Luzula multiflora (Retz.) Lej. Immature woods. W. McClain 1103.

Liliaceae

Erythronium albidum Nutt. Mature woods. W. McClain 1122.
Erythronium americanum Leichtl. Mature woods. W. McClain 1091.
Ornithogalum umbellatum L. Roadside. J. Ebinger 12479.
Trillium gleasoni Fern. Mature woods. W. McClain 1153.
Yucca filamentosa L. Roadside. J. Ebinger 13043.
Naias minor L. Pond. J. Ebinger 13057.

Orchidaceae

Aplectrum hyemale (Muhl.) Torr. Mature woods. J. Ebinger 12622.
Liparis lilfolia (L.) Rich. Immature woods. W. McClain 429.
Liparis loeselii (L.) RIch. Marsh. W. McClain 1186.
Spiranthes ovalis L. Mature woods. W. McClain 730.

Typhaceae

Typha angustifoila L. Roadside ditch. W. McCLain 466.
Typha latifolia L. Roadside ditch. W. McClain 465.

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Indiana Plant Distribution Records

Richard Maxwell and Jon Norman
Indiana University Southeast, New Albany, Indiana 47150

Genera are listed in the order of their appearance in Deam's *Flora of Indiana* (1); species within each genus are in alphabetical order, followed by the county in which they were collected. Nomenclature is in accord with that used in Gray's *Manual of Botany*, 8th ed., 1950 (2), unless modified as noted, following Mohlenbrock's *Vascular Flora of Illinois* (3). Specimens collected are mostly Floyd county with several from Clark, Harrison and Jefferson counties of Southern Indiana.

Ray Weatherholt of Floyd Central High School collected the majority of specimens from Floyd county. Ray was assisted by his students, Steven Barger and F. Gohmann.

Specimens were also collected through the herbarium and botany classes at Indiana University Southeast by Sharon Applegate, Jan Baker, Ann Chambers, O. M. Barker, Donna Clark, Jerry D. Conrad, Cindy Denman, R. A. DiNoto, P. Downey, Charles W. Henson, Kathy Hoeferlin, Frank R. Howard, Greg Jones, Debb Kepley, Sheila Klein, Dennis Lopp, Steve Lawton, Janet Loftin, Gale Lowery, Richard Maxwell, Mark McCampbell, Jim McDaniel, Jon Norman, Wanda Pindell, Charles Pospisil, Richard Schoen, Greg Smith, Mark Speth, J. Swarens, Paul Ulrich, Kathy Waterman, and Randy Woolbright, Jr.

Voucher specimens for all new records are in the herbarium of Indiana University Bloomington. Many of the vouchers are mounted sheets given to the Indiana University Southeast Herbarium by Ray Weatherholt from the Floyd Central High School Herbarium. The authors wish to acknowledge our debt to Ray and commend him for his continued interest in the southern Indiana flora and passing that interest on to many of his students.

Taxonomic Entities

Onoclea sensibilis, Floyd. *Echinochloa crus-galli*, Floyd. *Paspalum pubiflorum* var. *glabrum*, Floyd. *Setaria lutescens* (= *S. glauca*), Floyd.

Asparagus officinalis, Floyd. *Hemerocallis fulva*, Floyd. *Polygonatum biflorum*, Floyd. *Trillium sessile*, Floyd. *Yucca filamentosa*, Floyd. *Dioscorea batatas*, Floyd. *Iris shrevei* (= *I. virginica* var. *shrevei*), Floyd.

Salix babylonica, Clark. *Carya ovata*, Floyd. *Carya tomentosa*, Floyd. *Corylus americana*, Floyd. *Quercus imbricaria*, Floyd. *Quercus muhlenbergii*, Clark.

Ulmus pumila, Floyd. *Celtis occidentalis*, Clark. *Morus alba*, Clark. *Maclura pomifera*, Clark, Harrison. *Pilea pumial*, Floyd. *Polygonum aviculare*, Floyd.

Mirabilis nyctaginea, Clark. *Mollugo verticillata*, Floyd. *Portulaca oleracea*, Floyd. *Saponaria officinalis*, Floyd. *Stellaria media*, Floyd. *Thlaspi arvense*, Floyd.

Coronilla varia, Floyd. *Melilotus alba*, Floyd. *Melilotus officinalis*, Floyd. *Lotus corniculatus*, Floyd. *Trifolium dubium*, Floyd. *Trifolium hybridum*, Floyd. *Trifolium pratense*, Floyd. *Trifolium repens*, Floyd. *Lespedeza cuneata*, Harrison. *Lespedeza stipulacea*, Harrison. *Robinia hispida*, Jefferson. *Robinia pseudoacacia*, Clark, Floyd. *Vicia villosa*, Floyd.

Ptelea trifoliata, Clark. *Chamaesyce supina* (= *Euphorbia supina*), Floyd. *Acer*

sacharinum, Floyd. *Aesculus glabra*, Floyd. *Impatiens biflora* (= *I. capensis*), Floyd. *Impatiens pallida*, Floyd.

Malva neglecta, Floyd. *Hybanthus concolor*, Floyd. *Osmorhiza longistylis*, Floyd. *Osmorhiza claytonii*, Floyd. *Chaerophyllum tainturieri*, Floyd. *Conium maculatum*, Floyd. *Pastinaca sativa*, Floyd.

Cornus florida, Floyd. *Asclepias syriaca*, Floyd. *Cynanchum laeve* (= *Ampelamus albidus*), Floyd. *Ipomoea hederacea*, Floyd. *Ipomoea pandurata*, Floyd. *Ipomoea purpurea*, Floyd.

Verbena simplex, Clark. *Verbena hastata*, Clark. *Verbena urticifolia*, Floyd. *Prunella vulgaris* var. *lanceolata*, Floyd. *Perilla frutescens*, Floyd.

Solanum americanum, Clark, Floyd. *Solanum dulcamara*, Clark, Floyd. *Catalpa bignonioides*, Clark, Floyd, Harrison. *Ruellia humilis* var. *humilis*, Clark. *Sambucus canadensis*, Floyd. *Dipsacus sylvestris*, Floyd.

Ambrosia artemisiifolia, Floyd. *Bidens aristosa* var. *retrorsa* (= *B. polylepis*), Clark, Harrison. *Bidens cernua*, Clark. *Bidens frondosa*, Floyd.

Cichorium intybus, Floyd. *Carduus nutans*, Floyd. *Cirsium discolor*, Clark, Floyd, Harrison. *Senecio aureus*, Floyd. *Senecio obovatus*, Floyd. *Sonchus asper*, Floyd.

Xanthium strumarium var. *canadensis* (= *X. italicum*), Floyd. *Xanthium strumarium* var. *glabratum* (= *X. pennsylvanicum*), Floyd.

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1. Deam, C. C. 1940. Flora of Indiana. Indiana Department of Conservation, Indianapolis, 1236 p.
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3. Mohlenbrock, R. H. 1975. Guide to the Vascular Flora of Illinois, Southern Illinois University Press, Carbondale, Ill. 494 p.

SCIENCE EDUCATION

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ABSTRACTS

The New IAS Fellowship Program for Secondary School Science Teachers. WALTER A. CORY, JR., Office of School Programs, Indiana University, Bloomington, Indiana 47405.——In an attempt to increase the science teacher's knowledge of a field of science, to enhance one's enthusiasm toward scientific research and teaching, and to foster communication between secondary science teachers and college/university scientists, the Indiana Academy of Science has instituted a fellowship program for secondary science teachers.

Teachers of science in grades 6 through 12 with at least two years of teaching experience who are members of the IAS are invited to consult with a college or university scientist at one of the graduate level institutions within Indiana and submit a proposal to the chairperson of the Committee on Secondary Science Teacher Fellowships by December 15 of the year prior to the summer the research is to be conducted. The fellowships consist of a stipend of $120 each week for up to ten weeks plus an allowance of up to $300 for supplies. In 1983, two teachers received support under this program. Cynthia Brown, a biology teacher at Hamilton High School, and Art Middleton, a chemistry and physics teacher at Rensselaer Central High School, performed research or development at Tri-State University and Ball State University, respectively. Cynthia and Art will describe briefly their efforts of last summer and explain how this experience might improve their teaching, help them work more effectively with student researchers, and so forth. In 1984, we hope to involve two or more additional teachers with financial support from the Academy and other agencies.

A New Zoo in Indianapolis. RICHARD G. FRANCE, Indianapolis Zoological Society, Inc., Indianapolis, Indiana 46218.——The current Indianapolis Zoo opened in 1964 and has shown steady growth in size, programs and services ever since. Like all zoos, it strives to offer good leisure time recreation and entertainment, be educational, conduct good practices that promote conservation of natural resources and carry out study projects to research areas of operation. It is an obvious focus of community pride.

The zoo has now reached a point where plans for a new facility are being developed. A 75-acre site on the west bank of White River in downtown Indianapolis has been identified as the location for the new zoo. Plans call for an animal census of some 2,500 specimens contrasted to the present zoo's 500 animals.

The zoo is planned to accommodate approximately 1,000,000 visitors annually. Planning teams of zoo, wildlife and aquarium authorities, combined with architects, construction designers, and zoo officials, are setting the themes and goals for a world premier zoo. The overall zoo theme strives to illustrate diversity of life and constant change in our environments. The design principle centers on major biomes of the world; the waters, the deserts, the plains, the forests, plus an animal encounters area and commons/people space.

The Indianapolis Zoo has always made education a keystone for its operation. The New Zoo is being planned to be as useful, flexible and pertinent for education as possible. Various groups of users and audiences, including educators from all areas, are meeting to discuss and examine all potential educational messages, programs, facilities and services.

The Master Plan program is completed and the schematics design phase is in progress, with facilities design to follow in the next several months. Construction of the zoo will begin in early 1985 and the scheduled opening is spring, 1987.

A Classroom-applicable Methodology for Evaluation of Maturation in Cognitive Structure. LINDA HAMRICK, Department of the Sciences, The Canterbury School, Fort Wayne, Indiana 46804.——Research has resulted in several methodologies for pursuing how closely cognitive structure in a student's memory parallels content structure, including digraph theory (R. J. Shavelson, The Journal of Educational Psychology, Vol. LXIII, 1972), word-association analysis (R. J. Shavelson, Journal of Research in Science Teaching, Vol. III, 1974), and computer-generated conversational maps (G. Pask, The British Journal of Educational Psychology, Vol. XLVI, 1976). These investigations have been particularly significant to science and mathematics instruction due to the volume and complexity of content covered, and the importance of clear interrelationships in order for technical knowledge to be useful to the learner. However, the complexity of these approaches effectively precludes their implementation in the classroom.

A technique has now been developed which can be utilized by the classroom science teacher, both to analyze students' cognitive structure as well as promote integration skills in learners at the same time. A course is analyzed by the teacher for the twenty to thirty major and minor concepts covered, with twenty or less recommended for the middle school level. The educator then arranges these concepts into a meaningful relationship on paper (e.g. electricity, nuclear reactions and mechanics would all be grouped under energy), which then becomes the criterion map against which student work is measured.

The concepts are then placed on cards which are shuffled and placed on the learner's desk, whose task becomes arranging the cards in the best way he or she feels the terms fit together. The students' resulting card arrangements, representing their cognitive structures of the concepts, are analyzed for similarity in grouping and sequencing to the teacher's criterion map. Results indicate that science students may be more proficient at perceiving relationships within concept groups, e.g. within the energy group, than between concept groups, i.e. perceiving the broader context of relationships. Over a four year period, however, from 5th to 8th grade, the ability of students to perceive relationships between major concept groups improved significantly with periodic cognitive-structuring exercises, while a control group did not exercise such an improvement. The indication is that through testing methods which encourage students to consider the structural interrelationships among concepts, it may be possible to both evaluate and promote structural knowledge; such a mechanism taps both definitional knowledge of single concepts and their interrelationships (G. M. Diekhoff, Journal of Educational Psychology, Vol. LXXV, 1983). The importance of interrelating and problem-solving in science suggests that the technique may be a useful one to science educators.

Rationale and Tactics for Increasing Scientific Investigation by Secondary School Students. SUSAN M. JOHNSON, Department of Biology, Ball State University, Muncie, Indiana 47306.——Many secondary school students graduate without learning that science is a way of searching for understanding of the physical world, and that they themselves

can become involved in intriguing investigations. These students are not alone, however, for many of their teachers also have seldom had the opportunity to define a problem, design an experiment, or experience the satisfaction of answering a question through investigation. The Indiana Academy of Science, through the Youth Activities Committee and its support of science fairs, the Science Talent Search, and the Junior Academy, has a strong tradition of encouraging secondary school students to get a taste of science. This presentation will address the growing Academy concern to help in-service teachers establish research programs in their schools. The paper also reports on the results of a program designed to give pre-service teachers: (1) firsthand experience in investigating a research question; (2) skills and experience in motivating and managing research efforts of ninth-grade science students who may have shown little previous interest in scientific endeavors; and, (3) confidence in their ability to incorporate a less-structured, more individualized research format in their teaching.

Oxygen Consumption and Osmoregulation in the Goldfish in the Student Laboratory. R. S. MANALIS, K. L. HOWARD and A. W. O'SHAUGHNESSY, Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805——Oxygen consumption under various experimental conditions was measured for goldfish placed in a simple perfusion chamber. A glass cylinder (25 mm X 180 mm; D X L) contained the fish which was perfused with various solutions. The inflow solutions were saturated with air using a gas washing tube connected to an air compressor. The solutions were put into a 750 ml Kelly perfusion chamber, and the fish was perfused due to gravity. The control of the perfusion rate of this system did not require the use of screw-clamps, but, rather, the use of about a 15 mm length of 20 guage (I.D.) Teflon tubing as the outflow tube limited the perfusion rate to about 10 ml/min. The height of the perfusion bottle was varied so that a perfusion rate of 10 ml/min was obtained; during an experiment, additional perfusate was added in order to maintain a constant fluid level and, thus, a constant perfusion rate. The chamber was constructed in such a way as to permit the rapid exchange of solutions when necessary and, most importantly, to collect both inflow and outflow samples under oil. That is, before a 100 ml sample was collected, about 5 ml of vegetable oil was put into the empty Erlenmeyer flask, and the tip of a Pasteur pipette, for the inflow sample, or the tip of the Teflon tubing, for the outflow sample, was placed beneath the oil. In 14 consecutive measurements of oxygen consumption in which oil was alternately used and not used, the outflow samples collected under oil contained 13% less oxygen than did those samples collected in the absence of the oil. The presence of the oil did not present any practical problems when the Winkler method was then used to determine the oxygen concentration in the test samples. This is because the same Erlenmeyer flask was used during the subsequent analysis. Except for the concentrated HCl, all reagents were added by burettes, whose tips were placed beneath the oil. A magnetic stirring rod was used in order to improve the reproducibility of formation of the floccular precipitate and to reach the endpoint of the titration. In addition to measuring oxygen consumption in an animal, the students gained specific experience in the relationship between osmotic stress and aerobic metabolism.

A Summer Course in Physics for Gifted Junior High School Students. VAN E. NEIE, Department of Physics Education, Purdue University, West Lafayette, Indiana 47907.——The STAR program at Purdue University is a two-week intensive session during which gifted junior high age students enroll in two courses of their choosing from among several alternatives. This paper describes a course in the physics of light and color taught by the author. Materials and activities are described along with a discussion of the pecularities of teaching such topics to gifted adolescents.

How Teachers of Various Backgrounds Solve the Problem of Sequencing Four Masses with a Pan Balance. STANLEY S. SHIMER, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.——Elementary and secondary teachers tend to use different problem solving techniques as they try to sequence four unknown objects according to their masses from the lightest to the heaviest. There were several techniques used by teachers. However, most of the elementary teachers used a double beam balance to compare one object with another. In general, the secondary teachers used the double beam balance to weigh each object and then to sequence them to solve the problem. The percentage of teachers who correctly sequenced the objects was higher for teachers who compared the weights than for teachers who weighed the objects.

A Simple Way to Produce 360° Holograms Using a Low-powered Neon Laser. F. R. STELDT, Indiana University at Kokomo, Kokomo, Indiana 46902.——A 360° hologram is a hologram which reproduces the front, sides and back of an object on one piece of film. The 360° hologram can then be viewed by walking around the transparent, cylindrical film holder. An apparatus has been designed, built, and tested which enables students to easily produce their own 360° holograms using a low-powered neon laser and the appropriate film.

The apparatus consists of reasonably priced materials most of which are readily available at local stores. The components can be assembled in just a few hours and the stability of the apparatus can be experimentally confirmed. The critical alignment for producing good 360° holograms will now take only a few minutes.

General Science Education in Indiana. ALBERT A. WILLIAMS, Department of Biology, Manchester College, North Manchester, Indiana 46962.——The scientific literacy of the general population has been criticized widely in recent years with important implications for the future of the United States. A survey of the science requirements of Indiana colleges and universities indicates that science is thought to be an important component of an undergraduate college education. However, the nature of the requirements and the curriculum choices available to students may not significantly improve the scientific literacy of the students after they graduate. Most institutions appear to provide a traditional discipline centered, content oriented approach to exposing non-science students to the natural sciences. A review of the available textbooks in my field (Biology) indicates that this approach is reinforced by the publishing industry, with most texts stressing the content of the discipline rather than the process of science. They, in fact, often make the process very difficult to discover.

The current situation is fixed in the nature of our institutional general education science requirements and course offerings. I suggest a rethinking, at the divisional level, of our goals in the science education of our non-science oriented students. Scientific literacy must be defined in realistic terms applicable to non-science graduates in light of what we expect years after graduation. The curriculum must then be structured to achieve these goals. An alternative to traditional content oriented survey courses is available and would benefit our students.

Modeling Teaching Strategies for Biology Laboratory Experiences

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Introduction

In order to develop an effective teaching scheme in the teaching laboratory we have found it necessary to first determine our teaching goals and then design laboratory exercises to fit these goals. We conducted surveys of laboratory manuals in the biological sciences (1,2) and found that often laboratory exercises maximized factual learning rather than meeting clearly defined teaching objectives. As science educators we believe development of scientific literacy among students should be a priority. Students should be given laboratory exercises that will help them develop scientific literacy. Our purpose is to model the relationship between scientific literacy and the laboratory experience.

Scientific Literacy

The term scientific literacy has been defined in various ways. We have chosen to use the description of Simpson and Anderson (3) which restates the dimensions of scientific literacy developed by Victor Showalter and his colleagues into objectives. This version facilitates linking the laboratory situation to an achievable objective. Simpson and Anderson designate that a scientifically literate person:

1) Has knowledge of the major concepts, principles, laws, and theories of science and applies these in appropriate ways.

2) Uses the processes of science in solving problems, making decisions, and other suitable ways.

3) Has developed science-related skills that enable him or her to function effectively in careers, leisure activities, and other roles.

4) Understands the nature of science and the scientific enterprise.

5) Has developed interests that will lead to a richer and more satisfying life and a life that will include science and life-long learning.

6) Understands the partnership of science and technology and its interaction with society.

7) Possesses attitudes and values that are in harmony with those of science and a free society.

Analysis of laboratory exercises enables the instructor to determine those objectives from Simpson and Anderson's list which apply. Often, individual exercises meet several objectives concurrently. For example, observations of cheek cells teaches cell structure (objective 1) and facility with a microscope (objective 3). More elaborate exercises can incorporate greater numbers of these objectives. For example, an experiment which involves chlorophyll extraction from spinach leaves, chromatographic separation of the pigments, and spectrophotometric determination of the absorption spectrum trains students to understand photosynthesis (objective 1), learn new techniques (objective 3) and interpret the data in a meaningful way (objective 2).

The Role of Experimentation

Exercises which have a pre-planned protocol primarily strive to fulfill objectives

1, 2, and 3 but fail to portray an accurate picture about the nature of science (objective 4). It is true that science involves lab techniques, data gathering, and interpretation, yet science is also a creative endeavor that moves through a series of steps that begin with a question and lead, ultimately, to a conclusion. Each step necessitates that choices be made, the success of the experiment depending on the ingenuity of the investigator. Cookbooked labs do not challenge the creative mind because the critical decisions, except for data analysis, are already made. Moreover, the experimental process as opposed to the cookbooked approach, more accurately depicts the events that lead scientists to establish an hypothesis as fact. By challenging the student to create an experimental design, the student develops the ability to process new information in their daily life (objectives 6 and 7).

Since experimentation is a critical adjunct for attaining scientific literacy, we need to look more closely at the dynamics of these processes. In order to address all components of scientific literacy an effective teaching laboratory needs to:

Identify those objectives being taught within an exercise.

Clarify the interactions between the desired objectives and the components of the experimental process.

The Model

Experiments are the mechanism through which new scientific information is generated and, therefore, all seven objectives flow directly or indirectly from it (Figure 1). An understanding of the nature of science and a meaningful appreciation (interest) in science stems from knowing what scientists do and how they do it. Consequently, these objectives fit within a hierarchial scheme in which understanding of the experimental process is an important prior step. In other words, one must understand how science works before one can fully appreciate its meaning and, in turn, apply that knowledge. The application of science (objectives 6 and 7) hinges on the ability to assemble facts within the context of making decisions that involve values and society. It is hard to imagine someone who is truly insightful about science and feels comfortable in applying scientific information, who is unfamiliar with the experimental process. Indeed a major problem in society today lies in the difficulty of conveying scientific information to a scientifically illiterate public.

Individually, objectives 1, 2, and 3 are not dependent on each other or the experimental process. It is typical of science courses to teach concepts, experimental techniques, and to include word problems independent of the laboratory. However, hands-on experimentation integrates the necessary technical skills, cognitive abilities, and knowledge in a unique way that synergistically helps achieve all of these objectives. By analyzing these three objectives within the experimental process, we will show how each is involved with an understanding of experimentation.

The objectives represented by boxes in Figure 2, are attained by input from various steps in the flow diagram of the experimental process. A student who completes the entire process (i.e. conducts an experiment of their own design) will have been challenged more than once for each objective and several objectives are involved in some steps. The rationale for each interaction between objective and experiment is given below:

Objective 1) The initial phase of experimentation, (1) definition of the problem and (2) formulation of an hypothesis, draws upon pre-existing knowledge. Satisfactory completion rests on the student having a clear understanding of the direction the experiment will take. Experimental design can not proceed until there is mastery of these two steps.

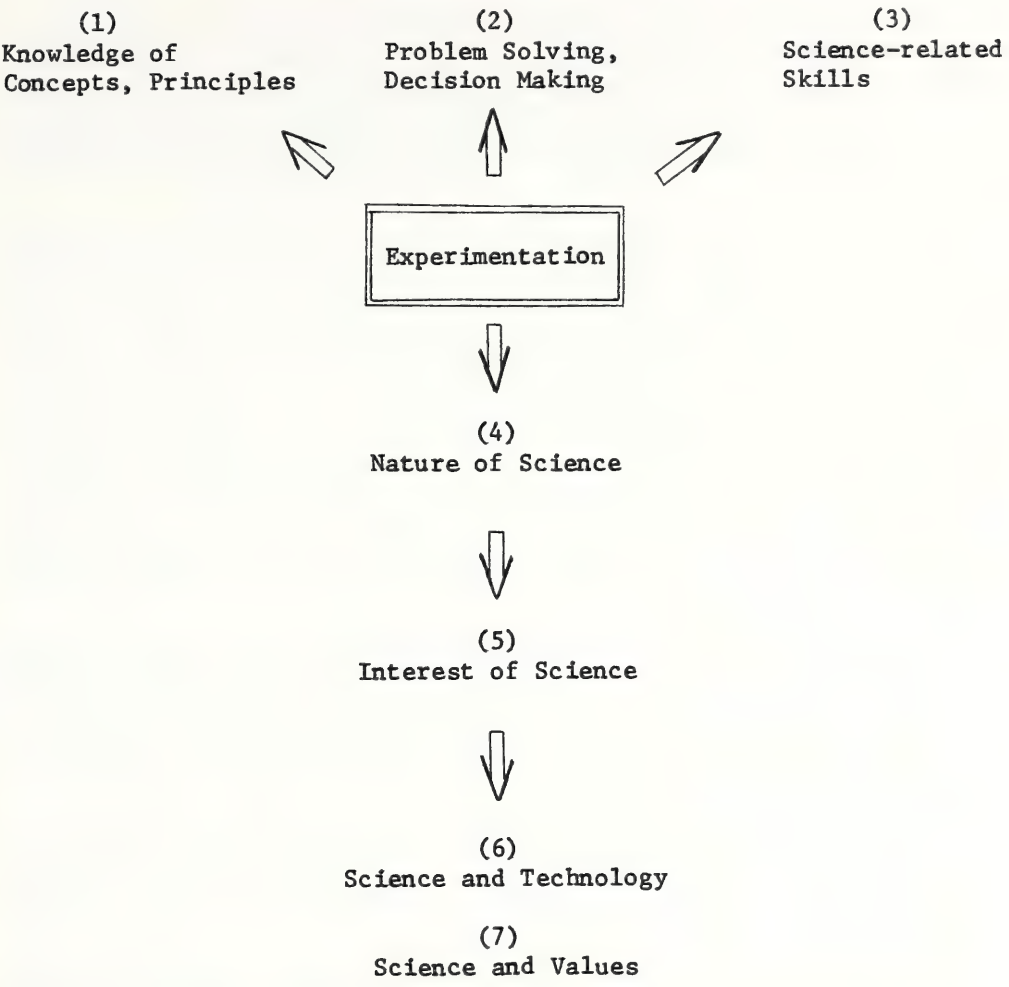

FIGURE 1. *Model depicting the relationship between experimentation in the teaching laboratory and Simpson and Anderson's seven objectives for scientific literacy.*

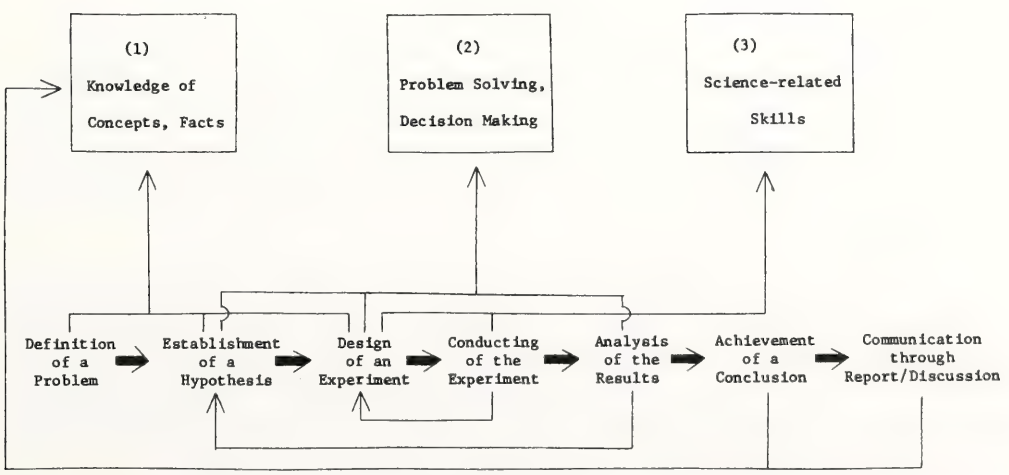

FIGURE 2. *Interaction between objectives 1, 2, and 3 and the stepwise experimental process.*

This objective also receives input in the form of a feedback loop from the conclusions. This signifies new information resulting from the outcome of the experiment. Because the loop flowing from knowledge back to knowledge is continuous, it is useful to have students propose a follow-up experiment that stems from their results and conclusions. This reinforces the idea that experimentation often leads to further experimentation.

Objective 2) This is the most difficult of these three objectives to attain and to teach. Typically, the weakest links in the experimental process lie in experimental design and data analysis. In both cases, a background in statistics and an ability to sort out variables become factors that limit success of beginning students. Lack of statistical expertise can be circumvented by emphasizing the need to carefully quantify observations, the value of including replication, and the importance of reaching objective decisions. Designing experiments to isolate variables can be a challenge to the veteran researcher, let alone the novice. Usually, students understand why this is important, but are often unaware of the vast array of circumstances that can influence biological processes. Most importantly, design and analysis of actual experiments is first hand experience that helps students to appreciate the influence of technical limitations, random variation, and human bias.

Objective 3) This is the capacity to utilize laboratory skills, particularly equipment, within the context of an experiment. It is an essential ability when conducting an experiment and for mapping out strategy for the design. Realization that technical problems can affect the success of an experiment encourages students to critique the strengths and weaknesses of their own plan.

Feedback loops within the flow diagram indicate that experiments sometimes need refinement before a meaningful conclusion can be drawn. Starting over can be frustrating for students and time consuming as well, but is a realistic component of the scientific method.

The final step in the flow diagram is important because scientific information is not useful unless it is communicated in some fashion. For the student, this may mean a data sheet, lab report, or class discussion. Students can achieve new insights and reinforcement via the act of writing and/or through the mutual exchange of ideas in discussion.

The Outcome

Attempts to teach the scientific method sometimes shortcuts the process by eliminating student-directed experimental design. Students begin by conducting the experiment and finish by drawing conclusions (and sometimes writing a report). Stunting the process eliminates involvement by the student in one of the most creative and important aspects of the experiment—the design. Further, the pre-planned experiment is so constraining that students never really sense the excitement of laboratory investigations.

The outcome of teaching science is, hopefully, a deeper understanding of the nature of science (objective 4) and indirectly objectives 5, 6 and 7. Direct experimentation is essential for developing scientific literacy. No one step in the experiment develops this understanding; rather all are mutually reinforcing. Students who have experienced the complete experimental process will be more sensitive to the creativity needed by a scientist, and the difficulties of interpretation.

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Positive Benefits of the Agronomy Cooperative Education Program

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Introduction

In 1975, the Purdue University School of Agriculture initiated a Cooperative Education Program. This program was developed to meet the demands of the large increase in agriculture students with non-rural backgrounds. Presently, about 60 percent of the agricultural students nationally have urban and suburban backgrounds (Goecker, 1982)(2). Frequently employers or potential employers express concern that agricultural graduates are well prepared academically but fall far short in their ability to apply classroom material to solving practical agricultural problems. Employers stress the importance of students gaining as much practical experience as possible before graduation. The objective of Purdue University's School of Agriculture Cooperative Education Program is to provide this "hands on" experience for the undergraduate agricultural students (Fowler, *et al.* and Rhykerd, *et al.*, 1980)(1, 3).

How the Program Operates

The Cooperative Education Program requires 5 years, with four thirteen-week work periods, to complete the B.S. degree. Usually students become involved in the program during their sophomore year. The only criteria for entering the program is a "C" average and a desire for "hands on" experience. The prospective interns complete an application form for the program and then proceed to interview with participating employers. After accepting an offer, which may be for one or two school terms, the intern enrolls in Agronomy 390. This non-credit course is entitled "Professional Cooperative Programs in Agronomy" and currently requires the student to pay a fee of $189 per school term.

During each off-campus school term there is visitation by the Departmental Coordinator, providing an opportunity for discussion of the intern's progress. Near the end of each off-campus school term an evaluation form is completed by the immediate supervisor to indicate the strengths and weaknesses of the intern's overall performance.

Positive Benefits of the Program

Based on our experience with the intern program, we have observed positive benefits to the student and to the employers.

Positive benefits to the students:

1. *Evaluation of career goals*—Students have the opportunity to explore a variety of professional careers as well as considering permanent employment with a participating employer. Assignments in work areas involving sales, production, and research provide the rare opportunity for the student to determine the type of career he prefers while still in college. Consequently, the student makes better selections of coursework and is more highly motivated in studies after returning to campus.
2. *Financial assistance*—In addition to helping make career decisions, the internship is a means of financing an undergraduate education. Salaries may

vary depending on the student's background and experience as well as type of assignment. Most salaries fall within the range of $600 to $1300 per month.

3. *Interviewing skills*—As a rule the B.S. graduate has had limited experience with the interviewing process. On the contrary, graduating seniors that have participated in the Cooperative Education Program approach interviews with confidence since they have spent time preparing resumes and interviewing for internships. This results in more employment opportunities and usually commands a higher starting salary.

4. *Improvements in attitude, confidence and maturity*—From a counseling viewpoint, exciting personal changes occur in the intern's attitude, confidence, and maturity. During the internship, the student is exposed to the "real world" before graduation and thus knows more about what to expect in a professional career. These attitudinal changes are particularly evident as exhibited through enthusiasm and confidence when interviewing for further internships and upon graduation.

Positive benefits to the employer:

1. *Responsible and intelligent seasonal employees*—Many agri-businesses require additional employees during certain seasons of the year. Dependable temporary employees may not be available locally. Consequently, many farmers, seed companies, agricultural chemical companies and other agriculturally related agencies are anxious to offer students "hands on" experience for a three to six month period.

2. *Method of screening for permanent employment*—Many companies become involved in the Cooperative Education Program as a means for selecting permanent employees. The internship gives the company an opportunity to observe interns for the desired capabilities.

3. *Maintain contact with the University*—Most employers appreciate the opportunity to interact directly with the University. They become acquainted with the professors and learn of the latest research information in their area of specialty.

Summary

The Agronomy Cooperative Education Program, established in 1975, is the practical phase of the undergraduate education which brings the employer and student together for a professional experience. Our Agronomy "hands on" program motivates students toward career goals, teaches responsibility, prepares them for job interviews, builds confidence, and they "earn while they learn". Benefits to employer include "quality" seasonal employees, screen potential full-time employees, and strengthens ties with the University.

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A Survey and Comparison of Majors and Non-majors Introductory Biology Laboratory Manuals Emphasizing Content and Inquiry

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Introduction

Considerable recent attention has been focused on the role of non-majors science instruction within an overall college curriculum (5,6,15). Much of this concern relates to providing opportunities, within the framework of a college course, to engage in critical thinking. A logical corollary of this concern has been the role of the laboratory in non-majors science instruction. Within those introductory biology courses for non-biology majors that offer laboratories there are often the same conflicting goals that plague majors biology laboratory instruction. Specifically, these are the goals pertaining to breadth of coverage of biological topics, depth of content within each topic, and student involvement in the scientific method as they examine a particular topic.

The latter goal, that of student involvement in the scientific method, indicates that instruction in method (i.e., providing analytical tools) and not substance alone (i.e., providing factual data) should be a part of any introductory biology laboratory course. The recent literature abounds with advocates of the inquiry approach to laboratory instruction at both the secondary (1,3,16,17) and college level (2,8,12,14,18) as well as to courses that emphasize science as a dynamic process.

Fogle and Mould (4) recently surveyed twenty published general biology laboratory manuals for use in one- or two-term general biology courses for majors. They identified the major topics emphasized and determined the degree to which student involvement in experimentation existed for this series of manuals. As part of their studies Fogle and Mould concluded that while some of these manuals provided the student opportunities to generate and manipulate data, they rarely allowed them to become involved in original experimental design.

As a means of determining the current status of laboratories for non-majors biology instruction a similar survey study was conducted with seventy-five published laboratory manuals. These manuals represented the existing resources available for supporting majors, combined majors/non-majors, and non-majors introductory general biology laboratory courses. Within each of these three categories the survey 1) identifies the major topics included in the manuals and 2) estimates the level of possible student involvement in experimentation. Comparison between each user category, with regards to the above two parameters, is then possible.

Methods

Seventy-five general biology lab manuals were reviewed (listed in Appendix). These manuals represented an exhaustive collection (based on titles in Books in Print, 1982 edition) of published lab manuals designed for use in majors and non-majors biology courses of a one- or two-semester duration. Although each lab manual was evaluated individually, the data are analyzed holistically with no judgements being made on any one manual.

The seventy-five manuals were divided into three basic categories based on their

intended usage: 1) biology majors, 2) either biology majors or non-biology majors, and 3) non-biology majors. For analysis of content the biology majors category of forty manuals was further divided into one-term (15 manuals) and two-term (25 manuals) course lab manuals. For the inquiry analysis the majors lab manuals were considered as one group (40 manuals).

Since the organization of topics in lab manuals is somewhat arbitrary, there is no one consistent way of subdividing the possible topics in the biological sciences that would easily coincide with the organization of all of the published manuals. For reasons of comparison I chose to utilize the hierarchical division of biology utilized by Fogle and Mould (4). This system was flexible enough to permit listing a particular lab under more than one entry in the hierarchical list of topics. Six major areas, twenty-one topics, and thirty-six topics were identified. When evaluating a lab exercise it was not possible to indicate depth or breadth of coverage of that topic in this survey, merely whether present or not in the particular manual.

Assessment of the level of scientific inquiry based on analysis/evaluation of individual followed a similar pattern to that of Fogle and Mould (4). Each exercise was classified into one of three categories:

1. conceptual or informational experience;
2. data manipulation and interpretation exercise, or
3. student-designed experimental analysis.

The first category includes observational kinds of experiences. Dissections and observation-demonstrations that follow a precise, step-by-step set of instructions would be included in this category. The second category includes data manipulation. Data collection, rearrangement, and analysis are included in his category. The third category includes experiences in which the student designs an experiment, conducts the experiment, collects data, analyzes the data, and makes conclusions based on data collected.

Fogle and Mould (4) point out that this scheme is not aimed at measuring "components of higher level thought" (e.g., need to conceptualize, synthesize, or use abstract reasoning) as one goes from category one to three-type exercises. Although this learning theory may correlate well with these types of exercises, the major goal has been to separate the exercises based on their level of student involvement. Category one has the student as observor, category two as participant, and category three as designer and participant.

Results

Table 1 shows the coverage of topics in each of the four categories of lab manuals analyzed. A number of generalizations concerning topical coverage were suggested or apparent after scanning these data and notes made while reviewing each lab manual. First, within the majors manuals, topics occur more frequently in two-term manuals than in one-term manuals. Second, topics in majors/non-majors manuals occur with similar frequency to topics in a two-term majors manual, with specific exceptions. Third, when a topic is covered in all categories of manuals the frequency of inclusion of subtopics of a more quantitative nature is highest among majors manuals and lowest among non-majors manuals. Fourth, certain topics in vertebrate anatomy and physiology occur most frequently in non-majors manuals. Fifth, majors and majors/non-majors manuals usually follow the hierarchical scheme of topics as listed in Table 1; non-majors manuals are quite unpredictable in the arrangement of topics within a manual.

The Cellular/Molecular Biology area is generally well represented in all types of manuals. This is probably owing to the preception of many of these topics as examples

TABLE 1. *Coverage of Topics in Published Lab Manuals*

Major Area / Topic / Subtopic	Percent of Manuals Covering Topic			
	Majors		Majors/Non-Majors	Non-Majors
	One-Term (15)	Two-Term (25)	(20)	(15)
Cellular/Molecular Biology				
Use of Microscope	87	77	85	93
Magnification/Measurement	53	72	55	33
Slide Preparation	60	98	95	40
Dissecting Scope	8	48	60	40
Oil Immersion	15	21	10	7
Biochemical Analysis	95	75	60	73
Carbohydrates	95	38	60	20
Lipids	78	30	35	13
Protein/Amino Acids	95	36	35	13
Nucleic Acid	8	24	30	7
Enzyme Analysis	75	6	60	40
Simple Kinetics	42	49	15	0
Parameters Affecting Activity	56	85	65	27
Cell Biology	97	100	100	100
Plant/Animal Structure	100	100	100	100
Diffusion	62	88	90	93
Osmosis	81	88	95	87
Active Transport	26	36	35	13
Organismal Biology				
Metabolism	79	84	80	93
Aerobic Respiration	19	62	65	40
Anaerobic Respiration	72	76	75	93
Vertebrate Anatomy	69	100	100	100
Digestive System	74	94	95	93
Respiratory System	26	79	95	93
Nervous System	22	70	80	87
Circulatory System	61	88	95	93
Skeletal System	14	44	75	87
Muscular System	16	52	60	93
Vertebrate Physiology	58	88	95	93
Human Senses	42	52	50	93
Stimulation	6	44	45	13
Behavior	45	52	65	67
Taxis	26	41	20	53
Vertebrate Observation	21	52	55	53
Invertebrate Observation	28	30	15	40
Embryology/Development	79	96	100	93
Cell Division/Genetics				
Mitosis/Meiosis	95	100	100	100
Gentics	100	94	100	100
Human Genetics	55	86	85	93
Mendelian Genetics	84	75	50	67
Drosophila	15	43	45	27
Population	39	34	30	40
Botany				
Plant Structure	98	100	95	67
Photosynthesis	100	100	100	87
Isolate Pigments	94	98	90	67
Physiology	26	68	80	53
Growth	52	66	40	47
Diversity				
Animal Survey	44	92	75	47
Plant/Fungi Survey	40	94	75	20
Bateriology	40	80	60	40
Use of Dichotomous Key	24	36	25	20

TABLE 1.—Continued

Major Area / Topic / Subtopic	Percent of Manuals Covering Topic			
	Majors		Majors/Non-Majors	Non-Majors
	One-Term (15)	Two-Term (25)	(20)	(15)
Ecology/Population Biology/Evolution				
Ecology	58	76	90	93
Outdoor Experience	14	62	45	75
Monitor Population	40	68	55	20
Ecosystem Modeling	20	36	5	7
Evolution	24	28	30	20

of extremely basic or fundamental biological principles. The compound microscope, being a very basic biological tool and its use was explained in varying detail in almost all lab manuals. Related microscopic skills like slide preparation and use of the oil immersion lense were more frequent in majors or majors/non-majors manuals than non-majors manuals.

Biochemical analysis also was routinely included in most lab manuals. While some sort of biochemical exercise was present across-the-board the specificity varied greatly. One-term majors emphasized specific biomolecules, two-term majors decreased this specificity; combined majors/non-majors maintained the decreased specificity, and the non-majors had very few molecule specific exercises. Fogle and Mould (4) explained the decrease in specificity observed in going from one-term to two-term majors labs by suggesting a greater likelihood that such topics were included in the context of another topic in the two-term manual. I did not observe this during my analysis of these lab manuals. The choice to become less specific in biochemical coverage decreased despite increased space (pagination) is indeed difficult to explain.

Enzymes, with their very important role in living systems, were routinely included topics in majors or combined lab manuals. They were less frequently included (40%) in non-majors manuals. The quantitative or semi-quantitative sub-topics were covered with decreasing frequency as one went from majors to non-majors lab manuals.

Basic animal and plant cell structure were uniform components of almost all manuals. Diffusion and osmosis were also routinely treated. The topic active transport was rarely included, with non-majors manuals being least likely to include this particular subject.

Metabolism is usually included in majors or combined-use lab manuals; it is less likely to be included in non-majors manuals. When the topic is included, anaerobic respiraton, using yeast, is almost always part of the exercise. Aerobic respiration is less likely to be included. This is especially noticeable in the non-majors manuals.

Vertebrate anatomy, involving the dissection of either pig, frog or rat, were routinely included in all manuals. Exercises involving individual systems were least likely included in majors one-term manuals, and most likely to be found in non-majors manuals. While the selection of organ systems can often be influenced by the choice of organism (4), this was almost never the case in the non-majors manuals. All body systems were covered by use of a particular organ from another vertebrate, microscope slides, or in-text diagrams with few exceptions.

Vertebrate physiology was routinely and almost exclusively included for the non-majors by use of a lab on human senses. The physiology exercises in the other three

categories utilized a human senses lab and often added an exercise on electrical stimulation of the muscle.

Behavior exercises were included in all manuals about half the time. The non-majors manuals showed the greatest frequency of inclusion of each of the three behavior subtopics.

Embryology/Development was included in almost all manuals. Wtih rare exception this included a study of one or two organisms (frog, chick, starfish, or sea urchin) early stages of development. The non-majors manuals usually included (75% of the time) a section on human development. This topic was not usually covered in the other two categories of manuals.

Mitosis and Meiosis were included in almost all manuals and generally consisted of examining prepared microscope slides (onion root tip and whitefish blastula) for the former and model-making for the latter. Occasionally the models were supplemented with prepared microscope slides of meiosis in the grasshopper testis. A genetics lab or two is included in almost all manuals. A human traits exercise is almost always included, as well as an additional Mendelian exercise (often using *Drosophila* for major or combined, corn for non-majors). The inclusion of a number of Mendelian Genetics problems is high amongst majors and combined manuals and very low among non-majors manuals.

Most of the botanical topics are included with less frequency (especially plant structure) amongst the non-majors manuals. The basic process of photosynthesis is most regularly included in all manuals.

Surveys of organismal diversity are included less than half the time in non-majors manuals. If included, they usually deal with a few representatives of the animal kingdom. Often bacteria and their role in human life is a featured exercise. The more traditional survey exercises, in tremendously varying depth and numbers of exercises, are usually included in majors and combined manuals.

Ecology exercises were included more frequently as one moved from majors to non-majors labs, while evolution was not usually included in any of the manuals. The ecology exercises of a more quantitative nature (population monitoring and ecosystem modeling) were rarely used in the non-majors lab manuals.

Table 2 compares biological topics with respect to the level of student involvement in experimentation. It should convey a sense of the level of independence required by students when completing a particular exercise. The percentages listed are computed from the manuals that included each particular topic. The topics are placed into three broad groupings based on the combined percentage of categories two and three, and ranked from highest to lowest. The majors lab manuals showed that many topics were confined to conceptual and informational experiences, while others facilitated data manipulation and interpretation. Student-designed experiments were, however, found in very few manuals, coming from only eight of the forty majors manuals surveyed and confirms earlier, similar conclusions (4).

Evaluation of the combined majors/non-majors manuals shows the incidence of category two and three-type student experience to be even further decreased. While some data manipulation and analysis is included, student-designed experiments are a rarity, occurring in only a few of the twenty combined-use lab manuals.

The trend suggested above becomes acute as the last group of lab manuals is evaluated in Table 2. The non-majors lab manuals evaluation shows that there is almost no category two or three experiences included. Almost all exercises provide for con-

TABLE 2. *Biological Topics Categorized for the Level of Student Involvement in Experimentation*

	Percent of Lab Manuals Found in Each Category								
	Majors (40)			Majors/Non-Majors (20)			Non-Majors (15)		
TOPIC	1	2	3	1	2	3	1	2	3
Enzyme Analyses	10	80	10	25	70	5	93	0	7
Ecology	25	55	20	40	40	20	86	7	7
Plant Physiology/Growth	28	50	22	75	55	0	93	0	7
Metabolism	31	66	3	60	40	0	93	7	0
Behavior	44	41	15	65	30	5	93	0	7
Genetics	47	50	3	65	35	10	93	0	7
Biochemical Analyses	50	50	0	55	40	5	86	7	7
Photosynthesis	56	41	3	80	15	5	87	0	13
Cell Properties	66	31	3	75	20	5	93	0	7
Mitosis/Meiosis	82	18	0	100	0	0	93	0	7
Plant Structure	87	13	0	95	5	0	93	7	0
Vertebrate Physiology	87	13	0	95	5	0	93	7	0
Plant/Animal Surveys	100	0	0	100	0	0	100	0	0
Embryology/Development	100	0	0	95	5	0	100	0	0
Anatomy	100	0	0	100	0	0	100	0	0
Cell Structure	100	0	0	100	0	0	100	0	0
Evolution	100	0	0	100	0	0	100	0	0

ceptual or informational experiences. Two manuals of the fifteen examined provide some data manipulation or student-designed experimental analysis for some topics.

Discussion

Analysis of breadth of coverage between one-term and two-term majors manuals confirmed an earlier conclusion (4): Despite shorter time periods (one-term) few topics were sacrificed. The depth of coverage differs, but very few manuals exclude a topic simply because they were designed for one-term use. Those manuals designated for use in majors or non-majors courses show a small but noticeable decrease in topics covered from the major's more comprehensive list. These include biochemical analysis (and certain specific analyses), enzyme analysis, and organismal diversity. They further show a trend for inclusion of a slightly higher rate (than an major's manuals) of the following topics: Some aspects of vertebrate anatomy, vertebrate physiology, behavior and ecology. This trend is further exemplified by the non-majors lab manuals where there is a substantial decrease, as compared to major's manuals, in the appearance of these topics: Some aspects related to use of the microscope, various biochemical analyses, enzyme analysis, botany, and diversity. Concomitant with this decrease in topic emphasis is substantially increased emphasis on these topics: Most aspects of vertebrate anatomy, vertebrate physiology, behavior, and ecology.

A careful analysis of the decreasing and increasing emphases in the non-majors lab manuals, that takes into account the changes in subtopic coverage, lead me to the following comments: 1) Non-majors biology courses often emphasize human biology and their laboratories might be expected to de-emphasize botany and organismal diversity-related topics; 2) Non-majors biology laboratory manuals avoid traditionally specialized or semi-quantitative/quantitative topics that might require basic computational skills. These reasons might explain the decided differences in topic coverage noted between majors and non-majors lab manuals.

The desirable role of utilizing inquiry methods in biology or other science lab instruction has been clearly stated by many authors (2,3,5,6,8,9,10,11,12,13,14,16,17,18). Kennedy and Hickman (7) stated the recent advocacy of inquiry clearly:

> Students should have experience in seeking knowledge in the same way that research scientists do. Science should not be taught as a rhetoric of conclusion but as a dynamic process of asking questions and seeking answers. Students should investigate real questions; they should not simply demonstrate the verity of principles already established. They should become skilled in using the tools of the scientist: hypothesis, experimental designs (controls and variables), and methods and protocols of data collection, analysis and interpretation.

Despite the fact that some authors question the transferability of problem-solving skills attained by students through the use of inquiry-based methods of instruction (reviewed in 17), the vast majority of authors still favor this mode of instruction for improved laboratory instruction. They further indicate that future studies will eventually show evidence of gains in reasoning and general problem-solving ability following use of discipline-specific inquiry methods of instruction (17).

While the current literature abounds with suggestions for implementation of inquiry methods into general biology lab instruction (10,11,12,13), there is little evidence of its general adoption as evidenced by this survey of published lab manuals. Fogle and Mould (4) commented that all of the majors lab manuals surveyed by them fell well below an acceptable level (i.e., 20% of lab time) for independent student investigations. This meager level of inquiry is further reduced in combined majors/non-majors manuals and is almost nonexistent in non-majors lab manuals. One can argue that this is the level of instruction where teaching problem-solving (as these inquiry methods are supposed to accomplish) is most needed (1,15). Unlike courses for the biology majors, where these sorts of desirable skills can be achieved in a series of courses/experiences in following the introductory general biology course, it is often the only opportunity for science instruction in these students' college education.

Thus, it becomes apparent that most available published lab manuals cannot adequately support development of a general biology lab program, at any level, that is based on inquiry methods of instruction. To provide student-oriented independent investigation for general biology alternative sources of information will have to be sought or independently generated.

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Working with the Scientifically/Creatively Gifted in Research

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Scientifically, creatively gifted students certainly need recognition, but they also need to be nurtured. Though many experts have attempted to list the characteristics and then outline behavior modifications for them, most have failed.

Once you feel a student is a cut above the others, it is important to build confidence in him or her. The scientifically/creatively gifted are a different lot; they may be egotistical on one hand and terribly afraid on the other. The gifted do not view the world in the same manner as the remainder of the population, and although they have no time for trivia, they may sometimes be trivial in their societal interactions. The gifted are not necessarily better; they are simply more capable.

After the scientifically/creatively gifted have been identified, push them. Challenge them, and develop in them a healthy fear of mediocrity. These students must be encouraged to learn and assimilate, yet also not be afraid to use different approaches to reach their goals. Try to understand that they have the minds but not necessarily the drive or discipline, and that is the problem. Someone must help them become comfortable with challenge, and develop a higher degree of self-motivation. The scientifically/creatively gifted must not be allowed to see the world only from their viewpoint, but be able to productively communicate to others in a gentle manner, realizing not everyone has the same capabilities.

How does one identify the scientifically/creatively gifted? This type of student may assume several guises, ranging from that of a discipline problem to that of a quietly inattentive student. He may also be a high achiever or seem to be an underachiever. According to Brandwein (1975), these students possess high scholastic ability, predisposing factors such as persistence and questioning, and an activating factor provided by the teacher (2). This latter factor is one which needs much more emphasis today. Giftedness represents only potential; it must be encouraged by a nourishing social and intellectual climate (Barnes, 1974, Casserly, 1979) (1,3).

Encouragement

Too often the gifted are either ignored in the classroom because they don't need help, or they are embarrassed with overattention, thus drawing disdain from classmates. Working independently on research, however, provides opportunity for these students to develop a more involved student-teacher relationship which is better suited to particular needs and talents.

Encouragement is the first step. Amazingly, many of these students lack confidence in their own abilities. They do not view the world as others, and often this leads to putdowns or more subtle negative reactions from teachers, parents, and even friends. "Why can't you be like everyone else?" is a question not foreign to them, and it is this attitude which often inhibits creativity. Chasteen (1981) points out that the gifted have learned how to stifle their imaginative output, yet how can anything new be discovered if we demand in return only what has been already taught (4)?

Teaching is not just giving information; teaching is asking questions. If the gifted are not encouraged at a young age, they will often lack the necessary drive, persistence, and skills when they are later able to work with intellectual equals (Vernon, 1977; Khatena, 1978) (9,10).

Young women are particularly adept at only living up to societal expectations and no more, say some writers (Kaminski, 1982; Kahle and Lakes, 1983) (7,8). The gifted need friends and mentors to provide support, encouragement and opportunities of various kinds (Casserly, 1979; Kahle, 1983) (3,6). Again, scientific research allows each student to explore a world where there are challenges to be understood and met.

Organization

Once scientifically/creatively gifted students have been identifiifed and motivated, guide them along. Note the key word here is guide, not lead. **Educare**, the Latin verb from which the word educate is derived, means to draw out. An educator must be prepared to do this with each particular student and also handle any possibly idiosyncratic behavior. The gifted tend to pour out great ideas, then hesitate to organize or follow through with them. Research plans are needed, for not that many have both the curiosity and the manner or discipline with which to challenge their ultimate goals. This is where the educator's role is extremely important. Stress that creative thinking must be organized before it can eventually lead to any attempted proof.

Curriculum

Students of science tend to avoid those areas of the curriculum which seem boring and a seeming waste of time, or at least assumably unassociated with their goals. Yet good scientists are required to report findings in acceptable mathematical and English terms. In addition, students must also develop good communication skills, for scientists indeed have an obligation to tell their fellow citizens about the various aspects of scientific problems. Part of their gift of knowledge carries with it the burden of nurturing greater understanding of these problems in others.

Scientific research should be shown to encompass history, as in the history of previous work. English, as in oral and written communication, should be mastered. Mathematics used in documentation is also an area for necessary competence. After all, science is, according to Gowan and Demos (1964) (5), "a systematic study of natural phenomena by rationally planned experimentation and rational analysis of the results." It is the most powerful method known for gaining knowledge about the world in which we live.

Influence

Realize that teachers exert a great deal of influence; be supportive and encouraging. Remember that enthusiasm is contagious. When asked to isolate those qualities apparent in successful teachers, students have often listed demonstrating kindness, sensitivity and intelligence, making each student feel significant, and most of all, caring.

Educators must realize the needs of the gifted concerning achievement and recognition, and demand neither too much nor too little from their charges. After all, students are not superhuman, and neither are teachers. Don't expect to know all the answers to their questions. Peter Beidler, Professor of the Year, states, "I don't have to be an expert in something to teach it. I say, 'What do I want to learn?' and I bring my students along with me." In the teaching of Zen the highest compliment given a teacher is the surpassing of his knowledge by his students. If all we give our students is what we have and never encourage them to go beyond that, we are not truly effec-

tive. That extended knowledge in each of our students should be the ultimate goal for any challenging teacher of the scientifically or creatively gifted.

Challenge young people's minds and talents. Good grades and even praise are not enough to overcome boredom in the creative science student. Strive towards arousing curiosity and exciting imagination. Respond to the efforts of the gifted and stimulate their interests, even if they are not your own.

Hold up firm and high standards of achievement and behavior. The gifted still need standards imposed upon them so they can develop habits which are necessary for successfully continuing education. Don't confuse inhibiting creativity with the proper channeling of energies.

Dedication

Teachers should be prepared to give always more. They may be called upon to assume the role of resource person, counselor, friend, or even surrogate parent. Extra time is considered a matter of fact; scientific research and/or student questions can never be placed on a time schedule. Be available not only when the need arises, but also be prepared to take the initiative when you feel a need should arise.

The rewards of working with the scientifically/creatively gifted are great. It is gratifying to watch young people analyze a scientific problem, use their own abilities to solve that problem, and emerge with a viable solution. Also, it is good to remember that by educating and encouraging our students, we are quite possibly also educating and encouraging future colleagues.

Gifted students are often the most difficult people with whom an educator deals, but they are a definite, enjoyable challenge.

Summary

Science thrives on knowledge and motivated intelligence. Don't let those valuable assets become anything less than what they can be. Identify the scientifically/creatively gifted and encourage them. Provide an unstifling environment and help them respond not only to the challenges others give them, but more importantly to those challenges which arise within themselves. Students need strong role models to assist in organization and sustentation, but most of all they need someone to care about them as individuals. The growing pains of young scientists and their mentors are very real, but if the challenges are great, the rewards are even greater. Our participation in the education of tomorrow's scientists may be demanding, but the demands which come with excellence are always worth our effort!

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PSI and Piaget

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Each graduate of DePauw University must demonstrate a minimum competency in expository writing, quantitative reasoning, and oral communication. These competencies are demonstrated by satisfactorily completing a course in which one of these skills is emphasized along with the academic content. Such courses are designated as a W course, a Q course, and a S course respectively.

Not all entering freshman students are qualified to enter a W course or for that matter the introductory course in English Composition. Similarly not all students are ready to enter a Q course. These students are placed in a "developmental" writing course and a Q readiness course respectively. Placement is done by means of examinations which are administered during the orientation week in the fall. This paper is concerned with Q readiness. Q placement is ascertained using a Basic Mathematics Test, designed by the mathematics staff. It is an objective test of 50 items. The first 25 items assess Q readiness; it is patterned after the Whimby Analytical Skills Inventory (7). A score greater than 12.5 certifies the students as being Q ready. Items 26-50 which emphasize algebraic skills are used for calculus placement. A score of 15 or more qualifies the student for the beginning calculus course. Table 1 summarizes the percentages of the entering students who are not qualified for W, Q, and calculus courses respectively for the past three years.

TABLE 1. *Competencies of Entering Students*

Academic Year	Class Size	S.A.T. Averages Verbal	Math	Not Qualified for in W	Q	Percentage Calculus
1981-82	660	517	542	7.6	17.7	37.3
1982-83	676	508	552	7.7	16.7	44.1
1983-84	668	500	557	6.9	15.4	45.8

Students are placed in the Q readiness course, Introduction to Quantitative Reasoning, as the direct result of failing a placement examination over material which should have been mastered during the pre-college years. Traditional methods of instruction associated with teaching quantitative skills did not work initially; consequently, a new approach seemed necessary!

The Personalized System of Instruction, PSI, which is structured within the psychological theory of reinforcement through reward seemed ideally suited to serve as the instructional vehicle for Math 100. PSI seems best adapted for courses that have a structured and highly objective content as opposed to a subjective content. The salient features of PSI as outlined by Keller (3) include:

1. The PSI course is *individually paced*. Each student proceeds at his/her own pace through the course in which the content material is divided into a number of short, easily assimilatable chunks. Each student demonstrates competency in the material of each unit by passing the unit or module test with a perfect score before passing on to the next module. No penalty is assessed if the student fails the quiz.

2. The PSI course is *mastery oriented*. The prime objective is that the student learn the material; hence, s/he must demonstrate competency over each unit before moving onto the next. Negative stimuli to learning are minimized by not imposing a penalty for failure of any quiz nor constraining the student to learn within a set time frame. If the student fails to finish during the semester, s/he can finish during the Winter Term session in January. The industrious student can finish the course well before the end of the semester. During the 1981-82 academic year 16 students finished before Thanksgiving. In the 1982-83 academic year 8 students finished early.

3. The PSI course is *student-proctored*. Throughout the course the students interact directly with undergraduate assistants. These assistants answer questions, administer and grade quizzes which they immediately critique with each student, and decide if the mastery of the particular unit on the part of the student is sufficient to pass him/her along to the next module. Initially module tests were administered from 8:00 to 9:00 a.m. four days per week; presently they are given from 3:00 to 4:30 p.m. four days per week.

4. The PSI course uses *formal study guides to commercial information*. The text, *Arithmetic and Algebra* (5), is almost a programmed tome. The supplementary material for each of the fourteen chapters includes a content summary section which is written to provide greater insight into the academic content of the unit and in certain instances provide additional material. Examples of additional topics which are not included in the next include introduction to mathematical induction, graphing techniques including the ideas of interpolation and extrapolation, number bases, and the compound interest law. A practice module test with answers is an integral feature of each unit supplement.

5. The PSI course provides for *lectures and activities* that are meant for *enrichment and stimulation*. No lecturing is done on mathematical subjects. Student questions are answered on a one-on-one basis by the student assistants, the instructor, or at the Q Reasoning Center in the college library. To provide "enrichment" students meet in small groups once each week with the instructor. The topics treated are math anxiety, how people think, and how to solve word problems. Each will be discussed separately.

To deal with math anxiety the attempt is to make those, who have the problem, realize that it is real and that something can be done about it. The initial emphasis is that the PSI format poses no threat to them and that module tests can be repeated as many times as needed. Two formal sessions are organized for the entire class. One deals with test taking strategies with emphasis directed toward the objective examination. The other focuses on the phenomenon of anxiety with emphasis on recognition and self-diagnosis. Personnel from the counseling service of the University lead these sessions. Finally each student writes his/her math autobiography in which the good and the bad experiences that they have had with math are discussed. Typical comments include:

> ". . . I hated math all through my childhood. I really never knew my multiplication tables. Grammar school mathematics was a disaster. . . ."
>
> ". . . I also remember being in the slow math groups in the third grade. My best friend was in the higher group. I had to take my math home and finish it over the summer. My parents were always helpful, but I always felt a little ashamed. . . ."
>
> ". . . In the ninth grade I ran into the meanest teacher I'd ever seen. She made me extremely embarrasssd and ashamed to ask any questions about

numbers. I began to struggle, became frustrated, and hated numbers. . . ."

". . . I started hating math when the teacher started giving fractions. . . . If I could do math I would be the happiest person on earth."

The enrichment exercises on how people think show that different students attack problems at different cognitive levels. Each student takes the Whimby Analytical Skills Inventory and a Piagetian exercise, the Frog Puzzle which measures proportional reasoning ability. These are graded by the instructor—no mark is placed on the papers—returned to the class and discussed during the next period. The author of this paper has given the Frog Puzzle to several classes. Their performances are summarized in Table 2. Over eighty percent of those enrolled in Math 100 tested concrete operation on the Frog Puzzle. The performance on the Whimby Analytical Skills Inventory will be discussed later.

TABLE 2. *Student Performance on the Frog Puzzle*

Class	Number	No Idea Percentage	Concrete Percentage	Transitional Percentage	Formal Percentage
Introductory Chemistry	56	2	41	25	22
Educational Psychology	32	0	63	12	25
Introduction To Quantitative Reasoning					
1981	56	6	73	9	12
1982	55	18	72	3	7
1983	48	21	72	2	5
High School Chemistry Class	12	0	67	8	25

A second exercise within the units was adopted from a Chautauqua Workshop (1), and is an introduction to Piaget's model for cognitive development. The students do four additional Piagetian Puzzles, The Algae Puzzle (combinatorial reasoning), The Islands Puzzle (propositional reasoning), The Ratio Puzzle (proportional reasoning), and The Mealworm Puzzle (propositional and probalistic reasoning), and the read the essay, "Piaget Simplified". They then are given a set of answers to these puzzles given by five other students. As a group they classify these five persons as being concrete operational, transitional operational, or formal operational. The Piaget categories of cognitive development are presented and discussed; in particular the process of self-regulation (6) is emphasized. The idea of the Learning Cycle as developed by Karplus (2) and its implications toward intellectual development is introduced. Finally the theory is put into practice. The group does two Learning Cycles which have been developed by the author, The Chemical Dilemma and An Empirical Approach to Probability. (Copies of these Learning Cycles as well as copies of the Piagetian Puzzles can be obtained by writing the author of this paper.)

The last facet of the enrichment material is a unit on how to solve word Problems. The idea for this unit comes from the paperback book, *Thinking Mathematically*, (4). Following a one period discussion concerning the structure of a solution to a mathematical problem, each section is broken down into groups of four students and problems are solved by committee. Each group presents its solution to an assigned problem to the remainder of the class. Since all groups work on the same problems,

if one group is stuck, the other groups or the instructor provides insight into the solution to the problem.

In this section the performance of the two classes who have completed Introduction to Quantitative Reasoning by Keller Plan pedagogy are presented. All students passed the fourteen modules that were constructed from the textbook material before they were permitted to take the final examination. The final examination consisted of re-administering the Whimby Analytical Skills Inventory and the Basic Mathematics Test, both the Q Placement and the Calculus Placement units. Students were placed in these sections by the Coordinator for the Quantitative Reasoning. Table 3 summarizes the Introduction to Quantitative Reasoning class make up. Notice that the last two SAT-M average is over 100 points less than the average of the freshman class. (Table 1).

TABLE 3. *Compentencies of Keller Section Math 100*

Class	Size	SAT-V average score	SAT-M	Q Placement average score	Calculus Placement
1981-82	62	462	476	10.7	6.8
1982-83	55	462	450	8.8	3.3
1983-84	48	464	415	8.6	4.9

The final performance of the two classes to have completed the Q readiness course using the Keller Plan are presented in Table 4. The performances of the women and

TABLE 4. *Keller Class Performance*

Keller Class Year	All	Women	Men
1981-82			
Number entering	62	40	22
Number withdrawing	8	2	6
		---- average scores ----	
Whimby Inventory	26.2	25.7	27.2
Q Placement			
before	10.7	10.4	11.1
after	16.2	15.6	18.4
Calculus Placement			
	before	6.8 5.5	7.4
after	12.0	11.6	12.1
1982-83			
Number entering	55	34	21
Number withdrawing	12	5	7
		---- average scores ---	
Whimby Inventory	22.3	22.6	21.8
Q Placement			
before	8.8	7.9	10.0
after	18.7	19.0	17.5
Calculus Placement			
before	3.3	3.0	3.6
after	8.3	9.0	7.0

men are compared as well as the class performance as a whole. Of those who withdrew from the course during the semester, six completed it during the Winter Term session in January. Of the 117 students initially placed in the course, 103 completed it. The average increase in the total score of the group on the Basic Mathematics Test was 12.6 points, Q Placement 7.5 points and Calculus Placement 5.1 points. The performance in the course correlates best with the student's initial effort on the Calculus Placement Test. This improvement is presented in Table 5. By not qualified for Q means that the person did not score at least 13 on the first 25 items of the test, and qualified for calculus means that the student scored at least 15 on the remaining 25 items. In only one case did the achievement on the Q Screening Test decrease; achievement on the Calculus Screening decreased in ten cases.

TABLE 5. *Initial Calculus Screening Score and Preformance*

Range	Number	Average Q Screening	Increase Calculus Screening	Number Not Q Qualified	Number Qualified for Calculus
Less than 0	6	8.8	7.7	1	0
0-5	47	7.2	5.5	2	5
5.25-10	31	6.3	5.1	3	13
10.25-15	11	4.6	1.7	2	7

Can the course be classed as a success. In certain instances demonstrated improvement was spectacular. In other cases improvement was at best only tentative. The one thing that did happen during the course was that every student worked problems and at least for a brief time demonstrated a certain competency in arithmetic and algebraic skills. The final question on the Module 14 Test was an anonymous questionnaire that tried to assess the impact of the course on the students. Ninety-five students answered the questionnaire. Sixty-two students preferred the Keller approach to the lecture format, seventy-two acknowledged that their math skills were improved, and forty-three students thought that their math anxiety had been decreased while eight thought that it had increased. Each student had the opportunity to comment about the course and suggest how it might be improved.

The most frequent suggestion was that there be class sessions in which formal lectures treat the mathematical concepts. While the students would feel more secure with this approach, to do this would weaken the most important impact of the Keller Plan, namely, the realization by the individual student that she/he mastered academic material which involved the use of quantitative concepts independently. I feel that the sense of accomplishment of self-learning by the student outweighs any improvement in personal albegraic skills that the student might realize within the lecture format.

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John A. Ricketts is shown in this photo presenting one of his papers during the Science Education Section meeting.

The High School Chemistry Laboratory Can Strengthen Abstract Reasoning Skills

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As the prelude I begin with a quotation that capsulates the impact that this study may have for science education at the secondary school level.

> "Andrea, who showed only concrete reasoning ability at the beginning, blossomed as the experiments progressed. One could actually witness her improved thought processes. She seemed to develop better lab technique over the course of the two and one-half months, and with each new experiment she approached it in a more scientific manner."

So wrote Lucy Brooks, chemistry teacher at West Central Boone Junior-Senior High School, who collaborated with me in this project.

The rationale underlying this study is the truism that abstract reasoning abilities are essential for the mastery of all academic disciplines. Yet, little formal attention is given to encourage the cognitive development of the high school student. As teachers we stress course content and pay little or no attention to how the student thinks. In Piagetian terminology we science teachers discuss many concepts that demand formal operational thought to students of only concrete operational ability. Herron (2) argues that as many as 50% of the entering college freshman operate entirely at the concrete operational level. McKinnon and Renner (4) on the basis of administering five Piagetian tasks to 131 college freshman at the University of Oklahoma found that 50% of the students were only concrete operational. Renner and Lawson (6) administered two tasks, one requiring the comprehension of volume conservation and the other variable exclusion, to high school students in the Norman, Oklahoma school system. Of the 196 high school juniors and seniors tested 51% were unable to apply the concept of conservation of volume correctly on the one task and 63% were unable to identify the correct variables on the variable exclusion task. If 50% of the entering college freshman only operate cognitively at the concrete operational level, is it any wonder that many find the first semester of college an academic disaster?

One of the authors was introduced to the use of Piagetian Puzzles at a workshop on "How People Think?" which was directed by R. Fuller and M. Thornton from the University of Nebraska-Lincoln (1). He has used one, The Frog Puzzle, which was developed at the University of California, to assess the capabilities of certain college classes to use proportional reasoning for the past three years. The essence of the Frog Puzzle follows; the results are summarized in Table 1.

The Frog Puzzle

An ecologists conducted an experiment to determine the number of frogs that live in a particular pond. Since he was unable to catch all of the frogs, he caught as many as possible, banded them, and released them back into the pond. A week later he returned to the pond and again he caught as many as he could. Here is his data.

TABLE 1. *Student Performance on the Frog Puzzle*

Class	Number	No Idea Percentage	Concrete Percentage	Transitional Percentage	Formal Percentage
Introductory Chemistry	112	4	38	21	37
Educational Psychology	32	0	63	12	25
Introduction To Quantitative Reasoning	159	14	72	5	9
Total	303	8	59	12	21
High School Chemistry Class	12	0	67	8	25

First Trip to the Pond

55 frogs caught and banded

Second Trip to the Pond

72 frogs caught, of these 72, 12 were banded.

In the week interval the ecologist assumed that the banded frogs had mixed thoroughly with the unbanded frogs. From this data he was able to approximate the number of frogs in the pond. If you can compute this number, do so. In the blank space below your answer, clearly explain how you calculated your result.

Total Number of Frogs in the Pond

In general the student responses fall into one of the following categories:

1. I have no idea.
2. On the first trip 55 frogs were banded, and on the second trip 12 of the 72 frogs were banded leaving 60 new unbanded frogs. Consequently, the total number of frogs is 60 + 55 = 115. (Concrete Reasoning)
3. Twelve of the 72 or one-sixth of the frogs are banded. Therefore, 55 = 1; N equals 330 frogs in the pond. (Formal Reasoning)
4. Of the 72 frogs 72 - 12 or 60 were not banded; consequently, 12/60 or one-fifth of the frogs in the pond are unbanded. Depending on the interpretation of the student, an answer of 275, 300, or 360 frogs is given. (Transitional Reasoning)

Of the 303 DePauw University students who were tested using the Frog Puzzle, only one-third of them utilized proportional reasoning. The chemistry class of 12 students at West Central Boone Junior-Senior High School were given the same Frog Puzzle. Their performance parallels that of the combined college group. This strongly indicates that cognitively the college-bound high school junior or senior student differs little from the average college freshman student.

The Learning Cycle described by Karplus (3) which was developed as part of the Science Curriculum Improvement Study (1970-1974) is a pedagogical technique that is specifically designed to encourage the introduction of formal concepts. The Learning

Cycle has the goal of strenghtening the reasoning ability of the student. Each Learning Cycle consists of three separate tasks and relies heavily on peer group interaction. Students learn from students rather than learning from the instructor who is present to guide inquiry rather than provide answers. The three phases are:

(1) Exploration which involves empirical observations of selected phenomena using the materials that are provided.

(2) Invention which develops laboratory technique, introduces quantitative calculations, and may demand the design of an experiment.

(3) Application which involves solving a problem using the ideas that are generated in the Exploration and Invention activities. In certain instances the Application activity may be an out of class exercise that demands formal reasoning patterns of the students.

The structure of the Learning Cycle makes it adaptable for use in a one-hour laboratory period format. Instead of doing Exploration, Invention, and Application as a three-hour exercise, they are done as three, one-hour exercises. During a National Science Foundation Faculty Development Fellowship at the University of Nebraska-Lincoln, one of the authors developed a set of Learning Cycles for use in the introductory college chemistry laboratory.

The realization that the average college freshman and the college-bound high school junior differ very little in their reasoning abilities prompted this study to see if the Learning Cycles experiments might be effective in encouraging the cognitive development in the high school student. Lucy Brooks tested this premise with her class of twelve chemistry students at West Central Boone High School. The class did the four Learning Cycles which are described below. The number in parentheses gives the number of single laboratory periods that are required to complete the experiment.

A CHEMICAL DILEMMA (2) stresses combinatorial reasoning which requires the student to analytically consider all possibilities and correlational reasoning which requires the student to interpret cause and effect relationships. Chemically the experiment involves an empirical study of precipitation reactions from which the student can identify certain aqueous solutions.

INDUCTIVE REASONING FROM CHEMICAL EXPERIMENT (4) demands both combinatorial and correlational reasoning as well as propositional reasoning which requires the student to identify variables and test certain hypotheses experimentally. A study of precipitation and filtration techniques permit the student to design and test his own scheme of qualitative analysis for any mixture of the cations, Hg_2^{+2}, Ag^+ Ba^{+2}, Al^{+3}, and Cd^{+2} using dilute solutions of HC1, H_2SO_4, HNO_3, NaOH, and aqueous NH_3.

THE PLOT THICKENS (5) emphasizes the construction and interpretation of a graph, the use of proportional reasoning which requires the understanding of the quantitative relationship between variables, and propositional reasoning. Using fractional crystallization techniques the student is asked to separate a mixture of sodium chloride and potassium dichromate.

THE GREAT TITRATION MYSTERY (10) demands correlational, proportional, and propositional reasoning. This experiment introduces titration techniques plus the concept of molarity and its use in chemical calculations. Students empirically investigate the behavior of strong and weak acids when titrated with strong base in the presence of various indicators. This is followed by standardizing a solution of sodium hydroxide which is then used to titrate an equimolar mixture containing two of the following

TABLE 2. *Cost of Experiments for 60 Students*

Chemicals	Learning Cycle	Description
$36.44	The Chemical Dilemma	Cost based on 500 ml. of 0.5 molar $BaCl_2$, $Pb(NO_3)_2$, $AgNO_3$, Na_2SO_4, and NaI.
$17.71	Inductive Reasoning	Cost based on 500 ml. of solutions, $Hg_2(NO_3)_2$, $Al(NO_3)_3$, $AgNO_3$, $Ba(NO_3)_2$, and $Cd(NO_3)_2$, containing 25 mg./ml. of the cation and 1 liter each of the dilute acids and bases.
$ 6.70	The Plot Thickens	Cost based upon the use of 1 lb. each of NaCl and $K_2Cr_2O_7$.
$ 2.95	The Great Titration Mystery	Cost based upon 500 ml. of 0.1 molar HCl, $HC_2H_3O_2$, H_3PO_4, and 2 liters of each of the acid mixtures which are 0.05 molar with respect to the acid. Included in the cost are the indicator solutions, potassium acid phthalate, and the NaOH solutions used in the titrations.

Equipment	Description
$225.00	30 Plastic Bottle Trays and bottles (30 ml.) with droppers.
$ 25.50	Pasteur pipets (1000) as substitutes for burets.
$ 10.00	Rubber bulbs for the Pasteur dropping pipets (50)
$ 22.00	18 Polyethylene wash bottles (125 ml.)
$500.00	18 Burets separable (50 ml.)
$ 31.80	6 Pipets (25 ml.)

three acids, acetic, hydrochloric, or phosphoric. The student is asked to deduce which pair of acids is in the mixture and the respective molarities of each.

These Learning Cycles can be done quite inexpensively. For a class of sixty students the cost is $63.81 for chemicals and $282 for the initial investment in equipment if Pasteur pipets are used in place of volumetric burets and pipets. Table 2 summarizes the equipment and chemical costs. Copies of the experiments are available upon request from the author.

The class was pre-tested and post-tested using five, pencil and paper puzzles which assess the cognitive development of the students. Pre-testing was done with The Frog Puzzle, which measures proportional reasoning ability, and The Islands Puzzle, which measures both propositional and combinatorial reasoning ability. The post-testing was done using The Ratio Puzzle, which assesses proportional reasoning ability, The Algae Puzzle, which measures combinatorial reasoning ability, and The Mealworm Puzzle, which requires both propositional and correlational skills. The student performances on these tests appear in Table 3. Copies of these puzzles will be supplied on request.

The small sample size and the absence of a control group preclude making any firm conclusions as to the effect of the Learning Cycles on cognitive ability. However, one does see that 1) those students who pre-tested formal operational remained formal operational, 2) no student's cognitive abilities decreased even though two of the group remained at the concrete operational level, and 3) seven of the group demonstrated significant improvement in their cognitive skills. Smith (7) describes a high school chemistry course that is designed to encourage cognitive development and reports that those students who participated in the course outperformed those students taking a traditional course on a test that required propositional logic, proportionality problems, and combinatorial analysis. Whisnant (8) uses twenty-five Learning Cycles in his college general chemistry course, however, he is uncertain as to whether they help the students develop cognitively. The one theme that appears in the articles involving the use of the Learning Cycle in the laboratory is that both the students and the instructors seem to enjoy this approach.

TABLE 3. *High School Student Performance on Piagetian Puzzles*

Student	Class	Pre-test		Post-test		
		Frog	Island	Ratio	Algae	Mealworm
1.	Jr.	C	C	F	F	C
2.	Sr.	Tr.	Tr.	F	C	C
3.	Jr.	C	Tr.	F	Tr.	F
4.	Sr.	N.E.	C	C	Tr.	C
5.	Sr.	C	Tr.	C	Tr.	C
6.	Sr.	N.E.	F	F	F	Tr.
7.	Jr.	F	F	F	F	Tr.
8.	Jr.	C	C	F	F	C
9.	Jr.	C	C	F	F	C
10.	Sr.	C	C	C	Tr.	Tr.
11.	Jr.	F	C	F	F	Tr.
12.	Jr.	F	C	F	F	Tr.

C - Concrete Operational Tr. - Transitional between Concrete and Formal Operational F - Formal Operational
N.E. - No evaluation possible.

As teachers of science we can use the laboratory to teach science skills and reasoning skills. To accomplish this, simply rewrite the experiments in a manner that will force the students to devise the procedure to test certain hypotheses and answer posed questions. Pickering (5) puts it this way,

"Confrontation with the unknown is good experience for all students regardless of their reasoning abilities."

My final admonition is to determine the reasoning abilities of your class. With the knowledge of their cognitive capabilities you will become a more effective teacher and they will become more effective learners.

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SOIL AND ATMOSPHERIC SCIENCES

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ABSTRACTS

Indiana Karst. Francis T. Adams, Purdue University, West Lafayette, Indiana 47907.——Much of the south-central portion of Indiana consists of limestone and dolomite bedrock at or near the surface. The terrain is characterized by classic karst features such as sinkholes, uvalas, caves, and subterranean cutoffs. These landforms present unique challenges for the geotechnical engineer when planning a transportation route or engineering structure in such an area.

Current research at Purdue University is being conducted to determine the best techniques for site investigation in karst regions. Remote sensing and geophysical techniques can be combined for an efficient investigation. Existing methods for sinkhole repair have been examined, and new techniques are being developed. Some of these techniques will be discussed in this presentation. Much of the current state-of-the-art practice will be reviewed so that the engineer can have insight into the unique problems and construction techniques required when working in karst regions.

Preliminary studies, such as consulting engineering soils, pedologic and geologic maps, as well as aerial photographs, can be used to locate areas where more detailed exploration should be conducted. Electrical resistivity and seismic refraction methods have been found to be the most efficient techniques for detecting subsurface cavities and soil-bedrock interfaces, respectively. However, this is not so in all situations, which will be emphasized. New techniques of sinkhole repair, such as using a reinforced earth wall as a slab to bridge over subsurface cavities, will be examined. All of the techniques, advantages and limitations, will be presented in a concise form.

Air Temperature Fluctuation in Indonesia During the Eclipse of 11 June 1983. William R. Gommel and Vivian P. Gommel, Department of Earth-Space Sciences, Indiana Central University, Indianapolis, Indiana 46227.——Using a sling psychrometer on the northeast coast of Java in Paciran, a reduction in air temperature of approximately 6.5° F from first contact (89.1° F just before 10 A.M. LST or 3 A.M. GMT) to the beginning to totality (82.6° F at 11:32 A.M. LST or 4:32 GMT). Wet-bulb temperature fell 3.9° F from 81.1° F to 77.2° F during the same period, and relative humidity increased from 70% to 79%. By 1 P.M. LST or 6 A.M. GMT, the temperature had increased to 88.2° F, as the partial phases were ending.

Duration of totality was approximately 5 minutes from 11:32 LST to 11:37 LST when the sun was high in the northern sky. Clouds were 0.3 cumulus, 0.2 cirrocumulus and 0.4 cirrus at the beginning of the partial phases. The cumulus diminished to only a few by the onset of totality while the cirrus remained essentially unchanged during the eclipse. By 1 P.M. LST, 0.4 cumulus had again reformed based at 2,000 feet. Excellent visibilities prevailed throughout the various phases of the eclipse. Surface

winds were generally from the southeast quadrant and less than 10 knots. Although surface winds were strongest during the hour preceding totality (accompanying a definite lack of onset of the sea breeze), a sudden increase in the surface winds or a compression wave was not observed as noted by the authors during the Norwegian and African eclipses of 30 June 1954 and 1973 respectively. Shadow bands (apparently an interference of light phenomenon) also were not as distinct as during the African eclipse of 30 June 1973.

Under similar total eclipse conditions over inland areas such as Indiana, air temperature fluctuations should be somewhat larger than those observed during this eclipse on the island of Java.

Digitized Soil Map of Fairfield Township, Tippecanoe County, Indiana. S. J. KRISTOF, S. K. HUNT and T. L. PHILLIPS, Purdue University, West Lafayette, Indiana 47907.—The process of converting soil maps to digital form is called digitizing. The software used for digitizing the soil maps described in this paper is written for an Apple II Plus computer and includes the capability of digitizing points and lines (ARCS), storing these data on disc and transferring it to the IBM 370/158.

The Fairfield Township data were digitized from USGS and soil maps, and merged to form a single map in latitude/longitude format. The soils of Tippecanoe County surveyed from 1939 to 1946 contain 179 codes which are stored with their definition in the computer. The soil image is stored as a series of pixels. Each pixel is 25 x 25 meters and contains one of the codes indicating the dominant soil type of the pixel. Therefore, the computer-stored soil data form a very useful base from which it is very easy to generate maps based on soil characteristics. In this study the soil properties considered in designing individual soil map units are: soil internal drainage, slope, parent material, taxonomic classification, soil productivity, organic matter content, soil color, wind and water erosion. The computer also provides information about the cumulative acreage (hectares) of the individual soil mapping units needed for publication of the soil survey. Each interpretive map is relevant to agricultural planners, farmers, economists, and other users interested in the evaluation of soil resources.

Environmental Effects on Ammonia Volatilization from Surface-applied Urea to *Dactylis glomerata* L. J. W. LIGHTNER, C. L. RHYKERD, D. B. MENGEL and T. P. MEYERS. Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.—Purdue University recommendations for nitrogen (N) fertilization of forage grasses have been based on research using ammonium nitrate primarily as the N source. Since the energy crises of the 1970s the economic advantage of producing solid nitrogen fertilizers has shifted towards urea. For many areas throughout the state of Indiana, urea is the only dry nitrogen source available to the forage producer.

The problem with using urea on grass pastures is that it cannot be incorporated into the soil unless it rains immediately after it is applied. Consequently, some of the nitrogen may be lost as ammonia gas to the atmosphere when urea undergoes hydrolysis. This loss is referred to as ammonia volatilization.

Ammonia volatilization resulting from topdressings of urea on grass depends on a number of conditions. A field experiment was conducted to estimate this type of nitrogen loss. Weather data were taken to account for environmental influences on ammonia volatilization. Under field conditions it was found that the rate of ammonia loss increased with increasing temperature. Furthermore, rapid drying of the soil-plant environment was a major factor influencing ammonia loss from surface-applied urea.

Induced Soil Compaction Alters Soil Physical Properties and Seedling Root Growth. GERRY L. SIMMONS, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907.——The decline in site productivity following the use of heavy equipment is often linked to soil compaction and its associated increases in bulk density and soil strength, decreases in total and macroporosity, and alterations in water and gas fluxes. The degree to which soil properties are influenced by compaction is dependent primarily upon texture and soil moisture content during trafficking. Changes in soil properties associated with compaction are greatest on well-graded soils with moisture contents near field capacity, but critical levels at which changes in these properties inhibit root growth have not been well defined for forest tree species. Simulation of a soil-tree-weather system by means of a bio-physical model is proposed as a method for describing soil compaction under different management practices and to predict whether the effects of a practice might be detectable in seedling root growth. Components of the model would include soil variables (bulk density, resistance, pore size distribution, infiltration rate, aeration), plant variables (root growth patterns, root geometry, size and distribution of feeder roots, root regeneration potential), and weather variables (precipitation, evaporation, air and soil temperatures). These components could be used in various combinations to identify levels in soil compaction suitable for plant growth and to predict seedling root growth responses for a range of soil conditions.

Comparison of Climatologies for Existing Heterogeneous Temperature Records with Those for Adjusted Records for West Lafayette and Whitestown, Indiana

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Introduction

Most published historical temperature records contain heterogeneities resulting from moves of the site of the temperature observations, changes in time of once-daily observations, change in instrumentation, and sometimes non-representative changes in the environment immediately surrounding the station (Nelson et al., 1979). Consequently we rarely have a true "climatological series", defined as a sample from a single population. Unless the historical temperature records are adjusted, statistical summaries can lead to misleading and biased results. In fact, at a time when there is concern about the increasing CO_2 in the earth's atmosphere and possible future climatic warming (Kerr, 1983), we should point out that "non-climatic" temperature changes in some weather station records may be as great or greater than the predicted climate warming in the next 100 years.

Since most all of the maximum and minimum temperatures published in Climatological Data (USDC, 1890-1980) have been observed and recorded from liquid-in-glass thermometers exposed in standard white, louvered instrument shelters, the primary sources of temperature heterogeneities have been changes in time of observation and changes in location, especially when the shelter has been moved to or from a roof. Rooftop locations usually affect minimum more than maximum temperatures because of the usual nighttime temperature inversions. Hence minimum temperatures observed at rooftop locations are usually higher than those observed at ground locations. Biases caused by time of observation at cooperative climatological stations result from the necessary procedure of setting the minimum and maximum thermometers at the time of the once-daily observation (Schaal and Dale, 1977). Since minimum thermometer readings for the next observational day cannot be higher than the temperature at the time of observation, a "set min" temperature at 7AM may carry over to the next morning, biasing daily minimum and mean temperatures downward. Since maximum thermometer readings for the next observational day cannot be lower than the ambient temperature at time of observation, a "set max" at 5PM may carry over to the next afternoon, biasing mean daily maximums and means upward. This is particularly vexing in those regions using daylight time during the summer, e.g., a 5PM daylight time observation is actually 4PM local standard time, increasing the bias.

The objective of this paper is to adjust for heterogeneities in two of the better climatological station records in Indiana, West Lafayette and Whitestown, about 80 km SE of West Lafayette, and to compare the temperature trends for the heterogeneous and adjusted temperature series.

Data and Procedures

An examination of the substation histories (U.S. Dept. of Commerce, 1955) and more recent substation reports (USDC, 1956-1982) for West Lafayette and Whitestown

showed that the Whitestown station had been in essentially the same ground location from January 1, 1909 to the present, with the same observer, Clyde O. Laughner, until 1965. Only the time of observation changed, from 6PM to 9AM on October 1, 1965 and to 7AM on July 1, 1967. This probably is the most homogeneous temperature record in Indiana. The West Lafayette temperature observations considered in this study began January 1, 1888 with a ground location on the Purdue University campus, observation time at 8PM. The instrument shelter was moved to the roof of the Agricultural Experiment Station Building July 1, 1917, about 18 m above ground. The time of observation was changed to 7AM February 1, 1949, and on July 1, 1953 the station was moved to a ground location at the Purdue University Agronomy Farm, about 6 miles northwest of the AES site, with observations taken between 7 and 8AM to the present.

The temperature records from 1890 to 1980 for West Lafayette (WLAF) and Whitestown (WHIT) were divided into six periods of "co-stable" locations and observation times, as shown in Table 1. Because both stations now have standard ground locations and the observation time preferred by the National Weather Service for operational purposes (Schaal and Dale, 1977), the mean temperatures for both stations were adjusted to correspond to their present status. The adjustments were determined with differences in temperatures, WLAF-WHIT, within periods. Mean daily maximum and mean daily minimum temperatures were adjusted separately. The adjusted mean temperatures were obtained by averaging the adjusted mean daily maximum and minimum temperatures, $(\overline{T}_{max} + \overline{T}_{min})/2$. Frequencies of different weather situations, such as frontal passages, fog and strength of temperature inversions, affect the temperature adjustments, but it was assumed that if individual adjustments were determined for each month there was a sufficient number of years in each period to give a reasonable estimate of the seasonal temperature adjustments.

The first step in the process was to adjust the Whitestown temperatures for the PM observational time in periods 1-4 downward to the present AM base in period 5. Since WLAF had the same location and observational time in periods 4 and 5, the only cause for differences between mean temperatures for those two periods at West Lafayette should be climate change, while at WHIT the difference results from changes in both climate and observational time. Assuming that the climate change at WHIT was the same as at WLAF, the adjustment factor used to correct the WHIT PM temperature records was computed in three steps:

TABLE 1. *Periods of co-stable weather station locations and times of observation for West Lafayette 6 NW, elevation 215 meters, and Whitestown Indiana, elevation 250 meters.*

PERIOD NO	PERIOD	YEARS	LOCATION	OBSV TIME
0	1890-1908	19	WLAF-ground	8PM
1	1909-1916	8	WLAF-ground	8PM
			WHIT-ground	6PM
2	1919-1948	30	WLAF-rooftop*	8PM
			WHIT-ground	6PM
3	1949-1952	4	WLAF-rooftop*	7AM
			WHIT-ground	6PM
4	1954-1964	11	WLAF-ground	8AM
			WHIT-ground	6PM
5	1966-1979	14	WLAF-ground	8AM
			WHIT-ground	7AM

* ROOFTOP 18 METERS ABOVE GROUND

1) $WL_{4-5} = WLAF_4 - WLAF_5 =$ CLIMATE change at both WLAF and WHIT between periods 4 and 5

2) $WH_{4-5} = WHIT_4 - WHIT_5 =$ CLIMATE plus OBSV time change at WHIT

3) [CWH, 4 ADJUSTMENT DIFFERENCE] = $WH_{4-5} - WL_{4-5} =$ [CLIMATE and OBSV time change] minus [CLIMATE change] = [OBSV time change ONLY]

This three-step process was applied in each month to both max and min mean temperatures for WHIT. These differences were used to adjust the Whitestown temperature in periods 1-4 to convert the entire record to an AM observation time.

The adjusted WHIT temperature record was then used as the base to adjust the WLAF temperatures. Again the climatic change at WHIT was assumed to be the same as that at WLAF, and a similar three-step process was used to determine the temperature differences needed to adjust the WLAF record to an AM observational time, ground location base. For example, the steps used to establish the WLAF corrections needed in period 3 were:

1) $WH_{3-4} = WHIT_3 - WHIT_4 =$ CLIMATE change at both WLAF and WHIT between period 3 and 4

2) $WL_{3-4} = WLAF_3 - WLAF_4 =$ CLIMATE change plus ROOF location change at WLAF

3) [CWL, 3 ADJUSTMENT DIFFERENCE] = $WL_{3-4} - WH_{3-4} =$ ROOF location change at WLAF

These same procedures were used to adjust WLAF temperatures for Periods 1 and 2. For period 2 adjustments, the subscripted 3's were replaced with 2's and the 4's with 3's in the above set of equations. Then to determine the adjustment for period 1, the subscripted 2's were replaced with 1's and the 3's with 2's. WLAF also had an earlier PM observation in period 0, when there were no WHIT records. Since the same base held for period 0 and 1, the same adjustments determined for period 1 were used for period 0.

The adjustments determined for the WLAF and WHIT temperature records were applied to the respective mean daily minimum, maximum, and mean temperature data series, and the adjusted temperatures compared against the original series.

Results and Discussion

The calculated adjustments for the published Whitestown mean daily minimum and maximum temperatures from January 1, 1909 to September 30, 1965 to make them equivalent to those for the present AM observational base are shown in Table 2 for each month and the year. The greatest adjustments at Whitestown were needed for the January and February mean daily minimum temperatures, which had to be decreased 2.5 F. No adjustment was necessary for August mean daily maximum temperatures.

TABLE 2. *Differences to be subtracted from the published mean daily maximum and minimum temperatures (°F) at Whitestown, IN, 1 January 1909 to 30 September 1965, to adjust them to an AM observation, ground location base for the indicated month and year.*

Month	Mean daily maximum temperature	Mean daily minimum temperature
J	0.6	2.5
F	1.2	2.5
M	1.9	1.7
A	1.3	1.5
M	1.1	1.0
J	0.7	0.5
J	0.2	0.5
A	0.0	1.0
S	-0.2	2.0
O	0.3	0.9
N	0.6	1.4
D	0.4	1.7
YR	0.7	1.4

At West Lafayette, the adjustments needed to make the mean daily maximum and minimum temperatures equivalent to those for the present ground location and

TABLE 3. *Differences to be subtracted from the published mean daily maximum and minimum temperatures (°F) at West Lafayette IN for indicated record period, to adjust them to an AM observation, ground location base for the indicated month and year.*

Period		0,1	2	3
Record Period	Month	1-1-1888 To 6-30-1917	7-1-1917 To 1-31-1949	2-1-1949 To 6-30-1953
Mean Daily Maximum Temp.	J	1.5	2.5	0.6
	F	1.8	3.3	0.8
	M	2.7	4.2	1.8
	A	2.4	3.3	0.8
	M	1.7	2.7	2.3
	J	1.7	1.9	2.6
	J	1.8	1.6	2.8
	A	1.7	1.6	2.8
	S	1.2	1.2	2.4
	O	2.1	2.5	2.6
	N	2.2	2.4	1.9
	D	1.6	1.8	1.1
	YR	1.8	2.4	1.9
Mean Daily Minimum Temp	J	1.1	4.2	0.7
	F	1.3	4.1	0.4
	M	1.4	3.3	-0.2
	A	1.2	2.7	0.8
	M	1.2	2.7	1.9
	J	-0.2	2.3	2.4
	J	0.5	2.7	3.5
	A	0.8	3.0	3.2
	S	2.2	3.7	3.0
	O	0.6	2.9	1.1
	N	0.8	3.1	1.0
	D	0.7	3.8	1.1
	YR	0.8	3.2	1.6

AM observations are shown in Table 3. With the exception of the differences calculated for the mean daily minimum temperature for June and September in periods 0 and 1, the adjustments display a fairly smooth seasonal pattern in Table 3, (as well as those for Whitestown in Table 2), and were not statistically smoothed. The largest temperature biases occurred during the winter in period 2, when there were PM observations and rooftop exposures. Daily mean minimum temperatures in January and mean daily maximum temperatures in March averaged 4.2 °F warmer than those recorded for AM observations at the present location. In the summer months the temperature biases for period 3 (rooftop and AM observations) were greater than those for period 2.

Unless these "non-climatic" temperature differences evaluated in Tables 2 and 3 are considered, these two stations give different estimates of the regional climatic change. For example in Fig. 1, the published annual mean daily minimum temperatures for West Lafayette and Whitestown have been plotted against year from the beginning

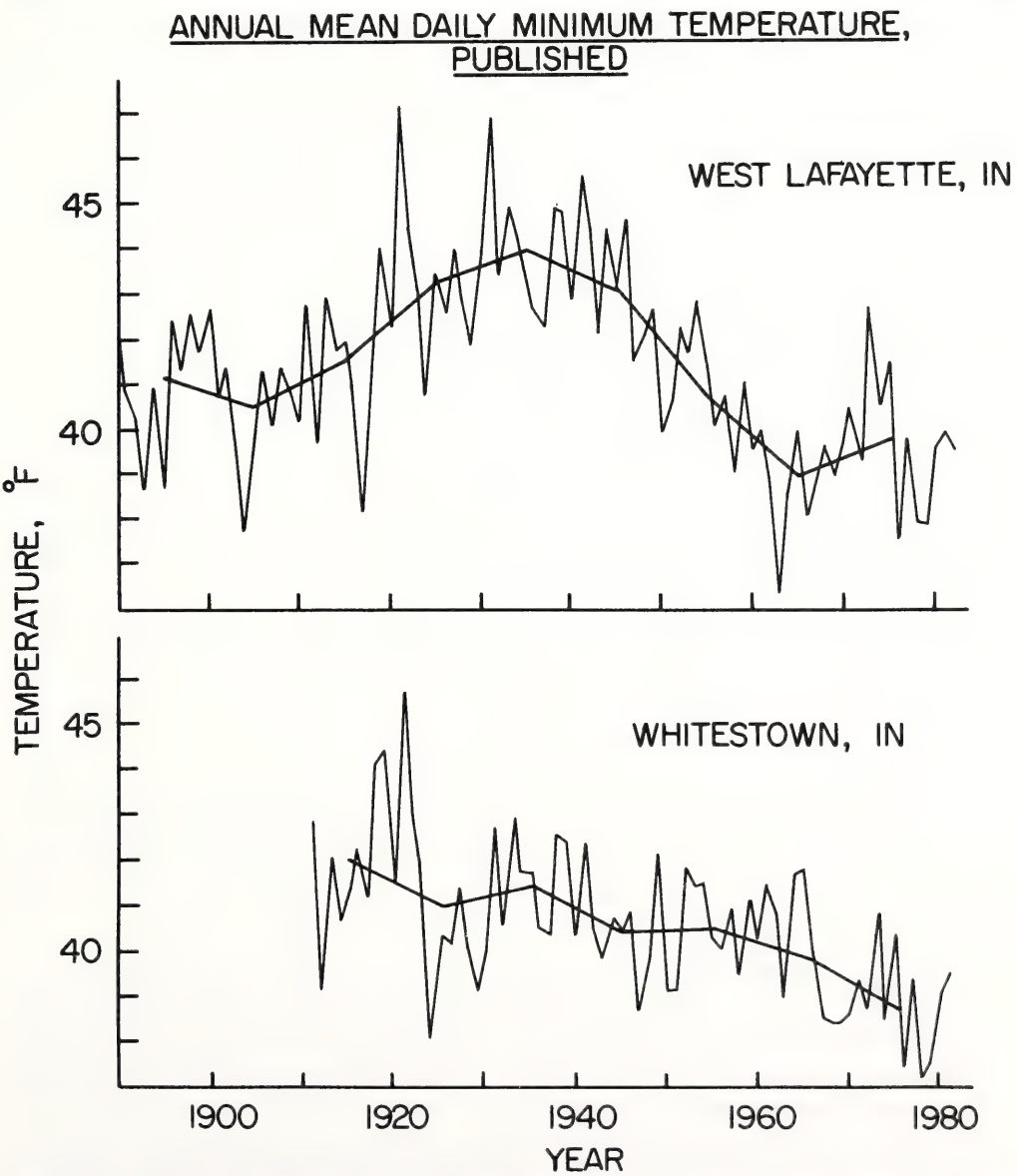

FIGURE 1. *Plot of published annual mean minimum temperatures on year for West Lafayette and Whitestown, IN. Heavy line connects average decadal (11-year) means plotted on middle year of decade.*

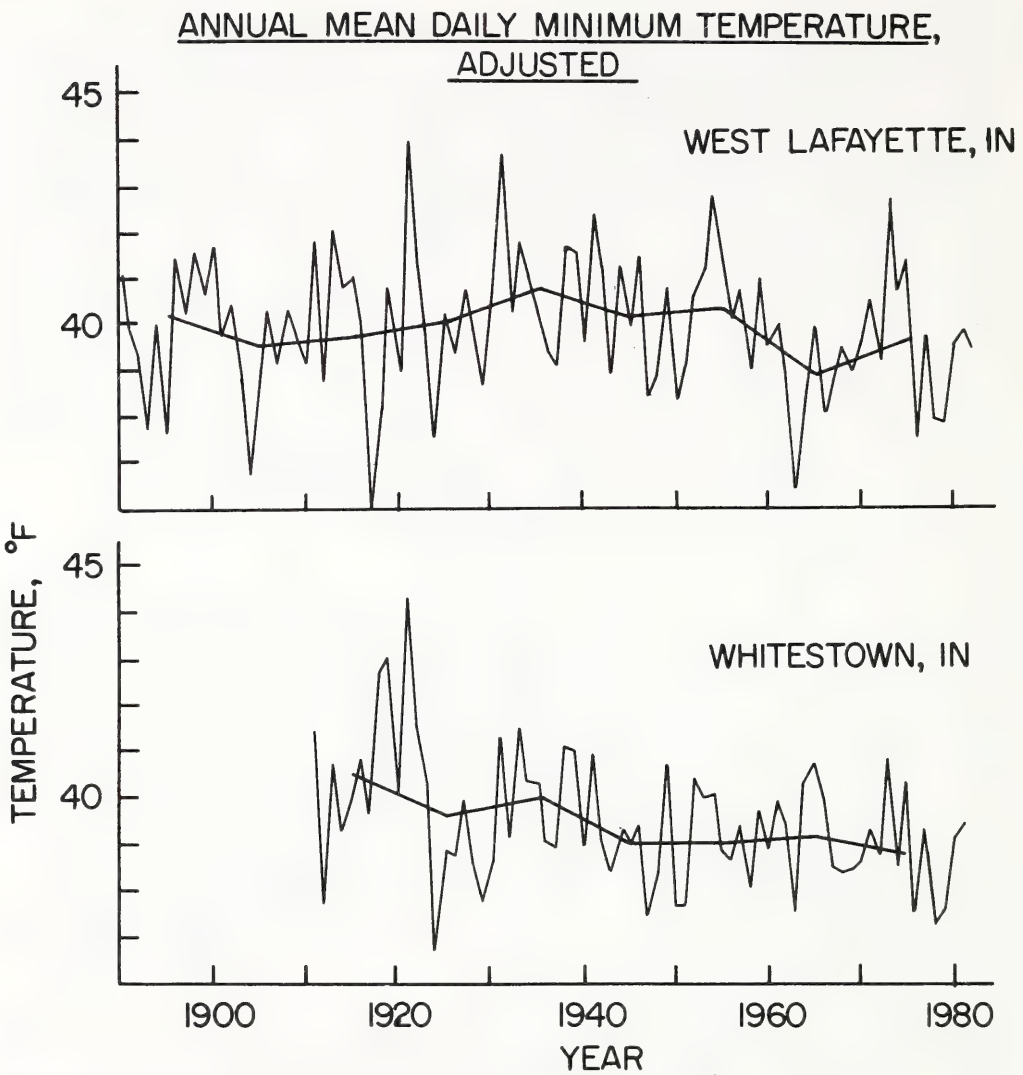

FIGURE 2. *Plot of adjusted annual mean daily minimum temperature on year for West Lafayette and Whitestown IN. Heavy line connects average decadal (11-year) means plotted on middle year of decade.*

of record through 1981. Decadal (11-year) means have also been plotted for the middle year of each decade to help show the climatic trend. The West Lafayette temperatures show a strong warming trend from the 1900s to the 1930s and then rapid cooling to 1960. On the other hand, Whitestown shows gradual cooling from the 1910s to the present.

The adjusted time series of annual mean daily minimum temperatures is shown in Fig. 2. Although there are still differences in the curves, the -3.2 correction (Table 2) for the period of rooftop temperature observations at West Lafayette decreased the warming in the 1930s, which had been artificially enhanced by the rooftop location and PM observations.

The annual mean daily minimum, maximum and mean temperatures for the five periods of published records are shown for both Whitestown and West Lafayette in Fig. 3. There are no consistent temperature differences between the two stations and five periods, minimums averaging lower at Whitestown than at West Lafayette in periods

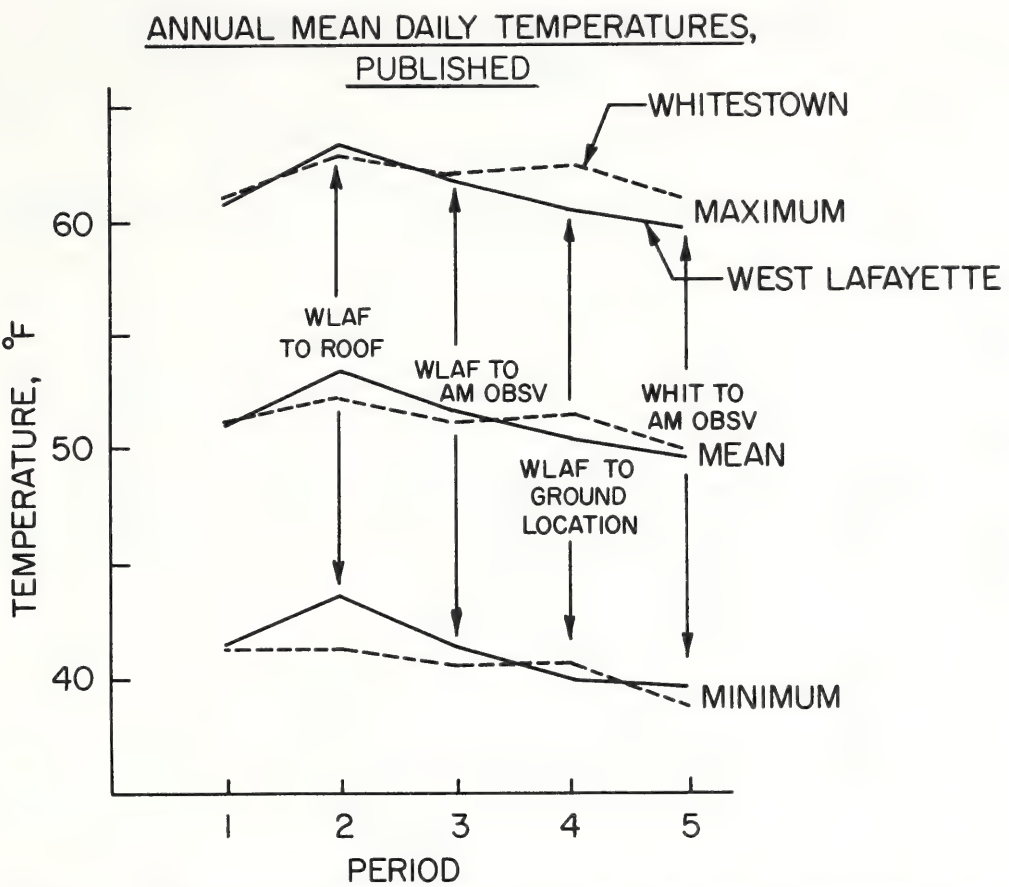

FIGURE 3. *Annual mean daily maximum, minimum and mean temperatures from published records for West Lafayette and Whitestown IN for indicated periods (Table 1).*

1, 2, 3, and 5, and above in period 4. After the temperatures have been adjusted the differences were much more consistent, as shown in Fig. 4. Plots of the differences between the published mean daily minimum and maximum temperatures at West Lafayette and Whitestown, WLAF - WHIT, showed great variability from month to month and period to period. For example in period 3 for the mean daily minimum temperatures, the WLAF - WHIT temperature differences ranged from between -1 to -2 °F in January, February and March to between +3 and +4 °F in July and August. When adjusted temperature records were used, the mean daily minimum temperature differences, WLAF - WHIT, typically ranged from near 0 in the winter months to near +1 for the fall months in all periods. Mean daily maximum temperature differences for the adjusted series ranged between -1 and -2°F for all months in all periods.

The usual statistic used by climatologists to show climatic trend is annual mean temperature. Decadal (11-year) mean temperatures have been plotted on the middle year of the decade in Fig. 5 for the published and adjusted West Lafayette temperatures, from the 1890s to the 1970s. The published curve is essentially the same as that reported by Agee (1980, Fig. 1), which shows the same warming peak in the 1930s as discussed previously for the mean daily minimum component of the mean. The adjusted curve still shows the warmest period in the 1930s but the climatic change has been cut in half. The range from the highest to lowest decade means for the mean daily minimum, maximum, and mean temperatures are shown for both West Lafayette and Whitestown in Table 4.

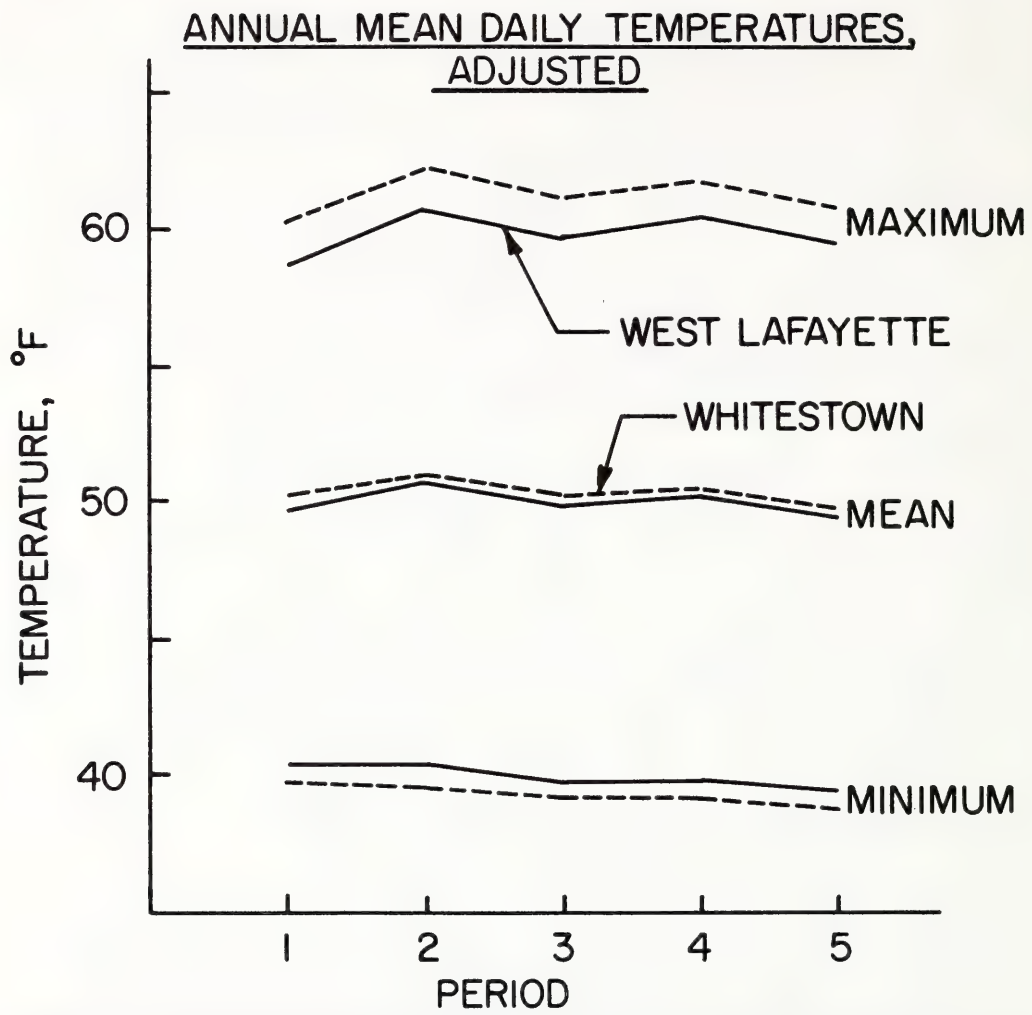

FIGURE 4. *Annual mean daily maximum, minimum and mean temperatures for adjusted records for West Lafayette and Whitestown IN for indicated periods (Table 1).*

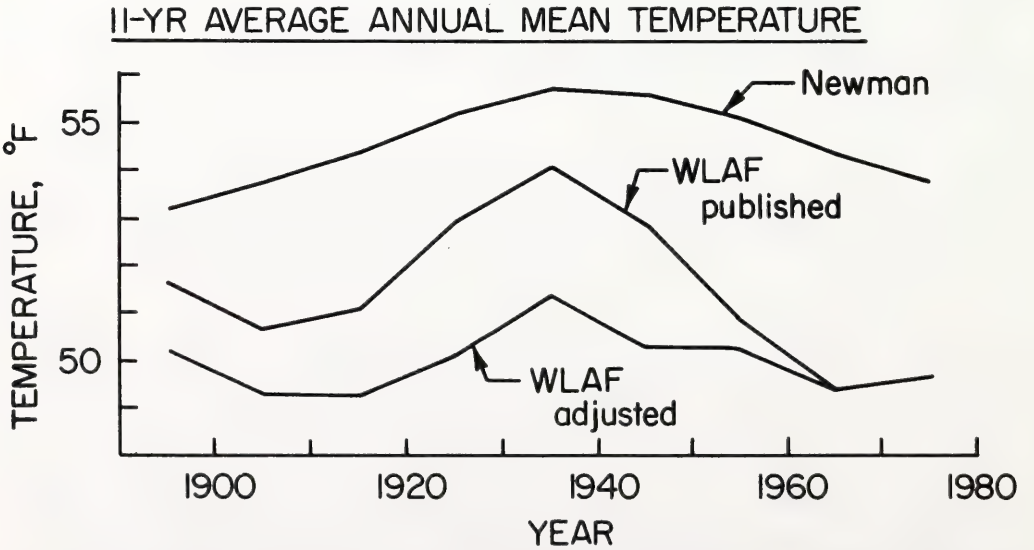

FIGURE 5. *Climate change over the past 80 years as illustrated for central Indiana by Newman (1982), the published WLAF record (Agee, 1980), and the adjusted WLAF record, using 11-year means of the annual daily mean temperatures.*

TABLE 4. *Range from highest to lowest 11-year average annual mean daily maximum, minimum and mean temperature for the published and adjusted West Lafayette and Whitestown records.*

		RANGE F°	
STATION	TEMP MEAN	PUBLISHED	ADJUSTED
WLAF	MAX	4.5	2.9
	MIN	5.0	1.8
	MEAN	4.7	2.0
WHIT	MAX	3.1	3.1
	MIN	3.2	1.7
	MEAN	2.7	1.6

A study conducted by Newman (1982) used the mean temperature obtained from five central Indiana stations (Greencastle, Indianapolis, Richmond, Rushville, and Terre Haute) to show the climate change in central Indiana over the past 100 years. Newman selected stations with no history of rooftop locations, but there were changes in times of observation, observers, and site locations. The range from highest to lowest 11-year means in the Newman study was 2.5 °F. Newman also reported the climate fluctuation for the entire northern hemisphere over the past 100 years was about 1.8-2.0 °F. The adjusted WLAF and WHIT temperature records compare favorably to these independent measures of climatic change, as opposed to the published records used by Agee (1980). Newman's 11-year means are also plotted in Fig. 5 to show that the general climatic trend agrees with that of the WLAF corrected record, although the more southern locations of the stations used in the Newman study result in higher temperatures.

Conclusions

The use of heterogeneous temperature records can produce biased results in climatological studies, and interpretation of these results can be misleading. In this paper, the climate change at West Lafayette, IN was interpreted as being extreme in its warming and cooling when the original published record was used. When the "non-climatic" heterogeneities in the record were removed, the general climatic trends of warming and cooling were decreased.

A must in any climatological study is the use of a climatological series. The biases inherent in the use of heterogeneous temperature data are transmitted to indices such as heating, cooling, and growing degree days as well as to timing of temperature threshholds. These indices are published and compared to those for past years regularly. If a temperature record contains heterogeneities, these indices will also contain biases, and may negate their use in management and planning studies. The results of any study can only be as reliable as the data which have been used.

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Determination of Aluminum Toxicity in Indiana Soils by Petri Dish Bioassay

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Introduction

A rapid determination of aluminum toxicity for a given cultivar on a particular soil would aid the investigator in making timely research or management decisions. Such a technique could be applied to survey acidic Indiana soils for phytotoxic levels of Al. Al injured roots are characteristically short, stubby, and lacking in fine branching. Root tips become thickened and turn brown (Foy 1978). Such roots are inefficient in absorbing nutrients and water. The degree to which Al toxicity symptoms are expressed is dependent on complex interactions among the amount and species of Al present in the soil (Pavin 1982), the presence of other toxic, essential and non-essential ions, the soil humus content, mineralogy and horizon, (Cedews 1981, 1983) and the plant genotype (Foy 1983). Because of this, chemical analysis of Al is a poor predictor of Al toxicity. In addition, the specifically toxic form of aluminum, and hence, the correct type of Al analysis, needs to be determined (Adams 1983). Recently, Pavin (1982) found that growth reduction of seedlings correlated best the Al^{3+} activity value, but the determination of Al activity requires a detailed knowledge of the chemical composition of the soil solution and the use of the GEOCHEM computer program to make the complex computations (Sposito 1980).

The purposes of this study were to develop techniques of using soil filled petri dishes for rapid root bioassays, to look at Indiana soils for the presence and distribution of Al toxicity, and to compare the results to various chemical parameters of the soil.

Materials and Methods

The small soil samples remaining from the Purdue Soil Characterization Laboratory analyses run for soil classification and mapping purposes were used to study horizons in pedons. Thirty-two horizons from eleven acid Indiana soils were wetted to field capacity and equilibrated for 12 hours. Al sensitive Abe wheat was germinated and selected for 0.5 cm root lengths. Square petri dishes measuring 9.0 X 9.0 X 1.5 cm were filled with soil and each planted with 5 germinated seeds, all placed 1 cm from the same edge of the dish. The dishes were taped shut, gently tapped to ensure good root-soil contact, placed vertically in a rack, covered with a plastic bag to retard moisture loss, and incubated for 48 hours in the dark. The seedlings were then removed and total root lengths per plant were measured.

Six replications were run for a total of 30 seedlings per horizon. Root growth in dishes was also compared to growth in pots using the limed and unlimed A and B horizons of an acid Cecil loam.

Root growth vs. pH relationships in H_20, 0.01M $CaCl_2$ and 1N KCl were examined. In addition, exchangeable acidity and Al were determined by 1N KCl ex-

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traction following the method of Thomas (1982). The values for pH and other exchangeable ions were taken from the Soil Characterization Laboratory analyses of these samples. Root growth was also compared to exchangeable Al and percent Al saturation.

For a reference system 20 ml of solution with varying concentrations of $Al(NO_3)_3$ was added to 200 g sand, placed in petri dishes and planted with 6 Abe wheat seedlings. The root lengths were measured after 48 hours of incubation. This experiment was conducted in randomized blocks with six replications.

Results and Discussion

No significant differences in root growth were apparent between petri dishes and pots in the Cecil loam study. This verifies that the small amount of soil and the close proximity of the petri dish surfaces to the roots does not affect the validity of the test.

Analysis of root length in Indiana soils showed root reductions in 20 of the 32 horizons, some as high as 60%. Ten out of the eleven soils studies showed significant root reductions, most of which occurred in the B horizons. These roots were thickened, with spatulate ends and few root hairs. Roots from sand systems containing Al showed similar root toxicities at higher Al levels. Incremental additions of Al to sand systems (Figure 1) showed a modest decline in root length to 5 mg Al/kg sand and a steep decline between 5.0 and 7.5 mg Al/kg. This suggests that there may be a critical level of Al for toxicity to Abe wheat in the region of the steep decline.

The occurrence of Al toxicity in the soils showed great variation and little adherence to any pattern. Figure 2 shows two soils with pH declining with depth. In the Peoga soil, the root growth declines with pH, but this clearly is not the case for the Clermont. Figure 3 shows differences in root growth versus horizon. A decline in root growth occurs on going to deeper horizons in the Avonburg, but this relationship does not hold for the Rockcastle.

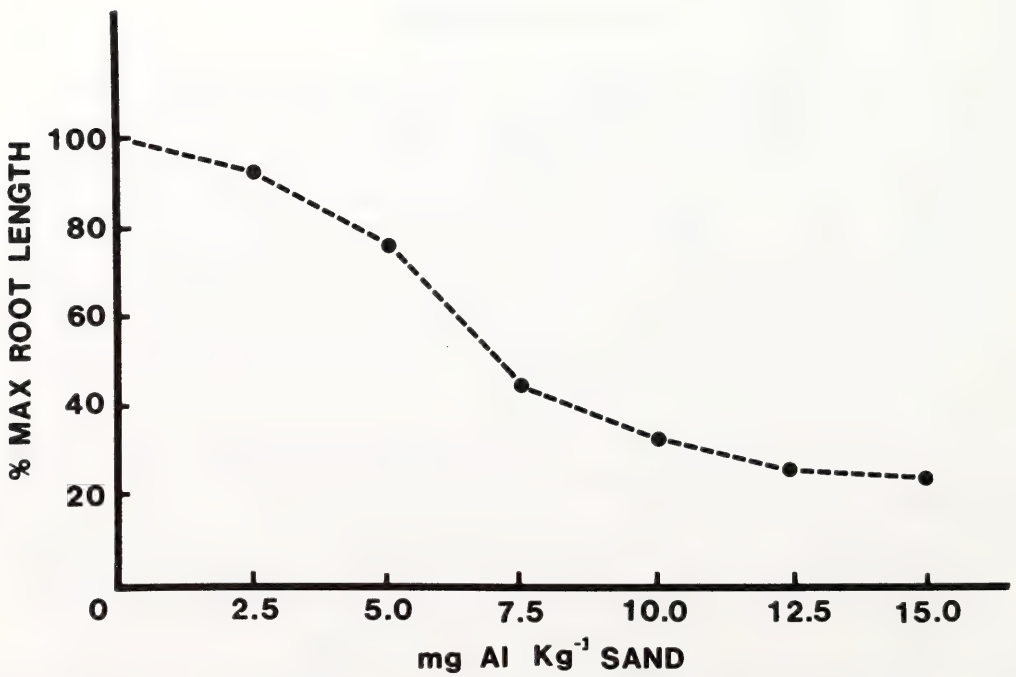

FIGURE 1. *The effect of incremental additions of Al to sand systems on root growth.*

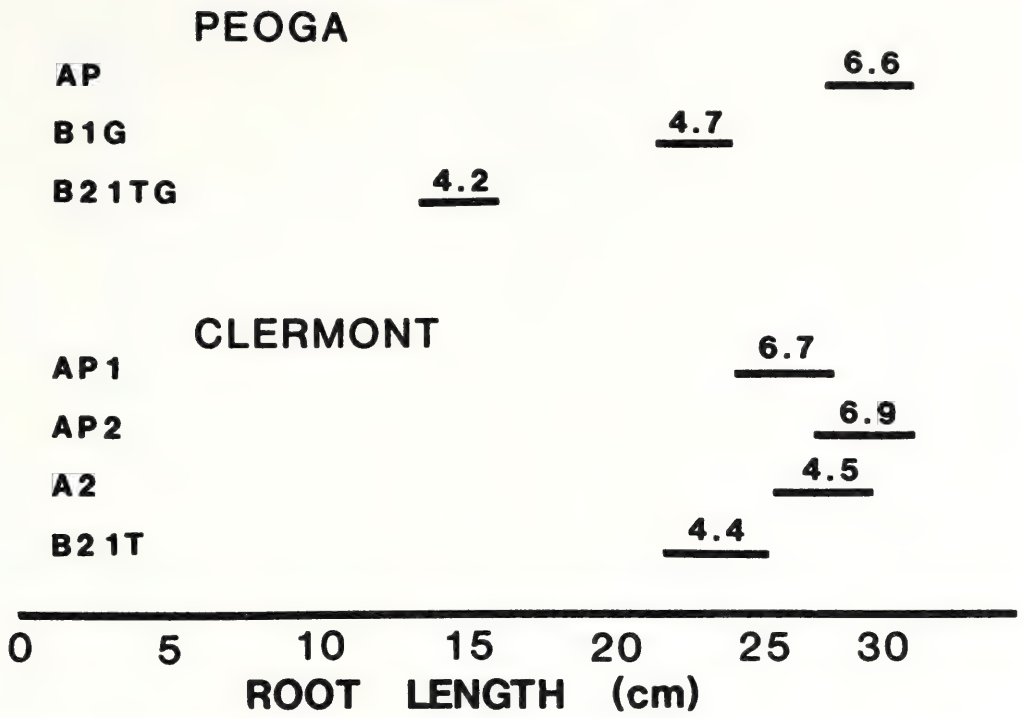

FIGURE 2. *Root length vs. horizon for the Peoga and Clermont soils, with pH shown. Line widths represent a 95% confidence interval for the population mean.*

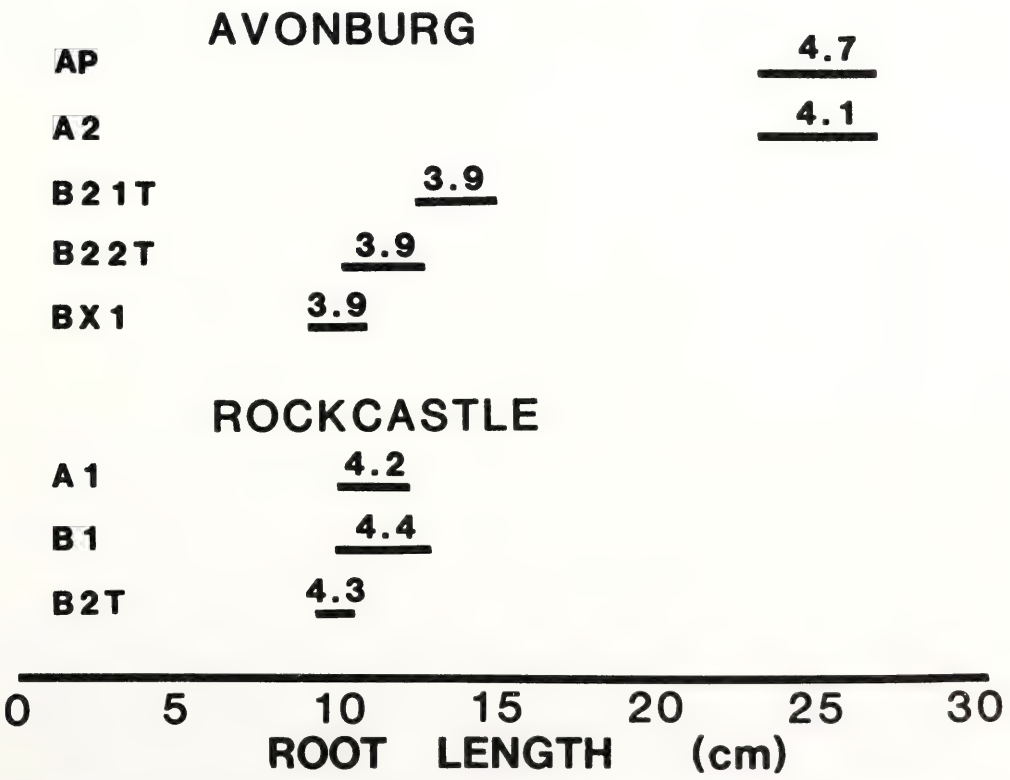

FIGURE 3. *Two soils showing root lengths at various horizons. pH in H_20 is shown above confidence intervals.*

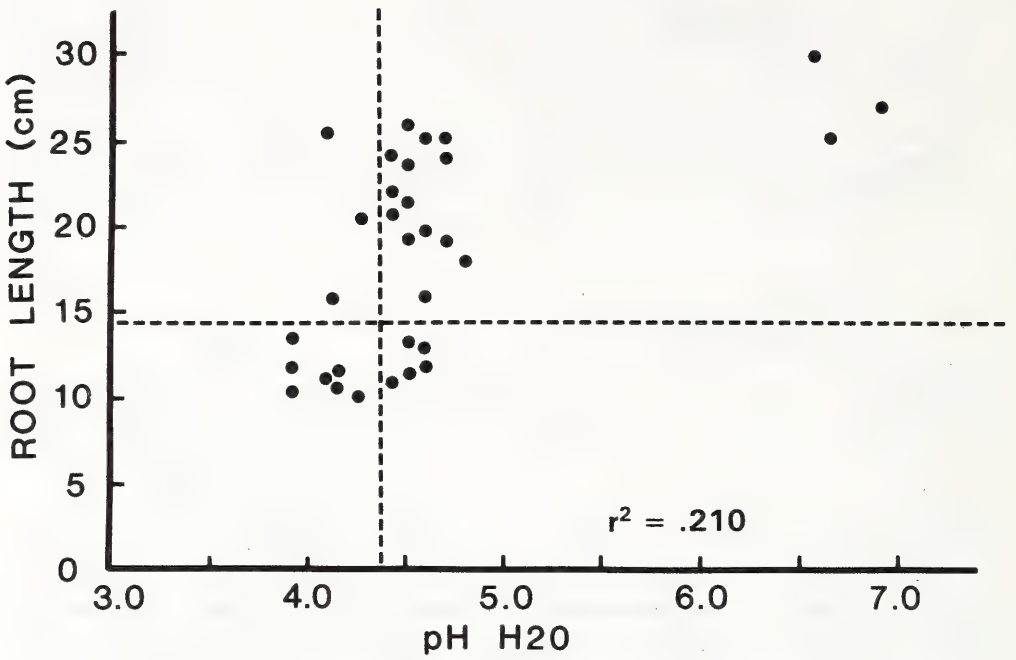

FIGURE 4. *pH in H_20 versus root length. Quadrants are drwan for Cate-Nelson critical level graphical analysis.*

In the acid range, where soil pH might be expected to cause toxicities, the root lengths showed almost no relationshp to pH in H_20 (Figure 4). This was also true for root growth vs. pH read in 0.01M $CaCl_2$. The relationship for pH read in KCl vs. root growth (Figure 5) is somewhat better. The Cate-Nelson critical level graphical analysis technique (1973) suggests that Al toxic symptoms for Abe wheat occur often at a pH (KCl) below 3.3.

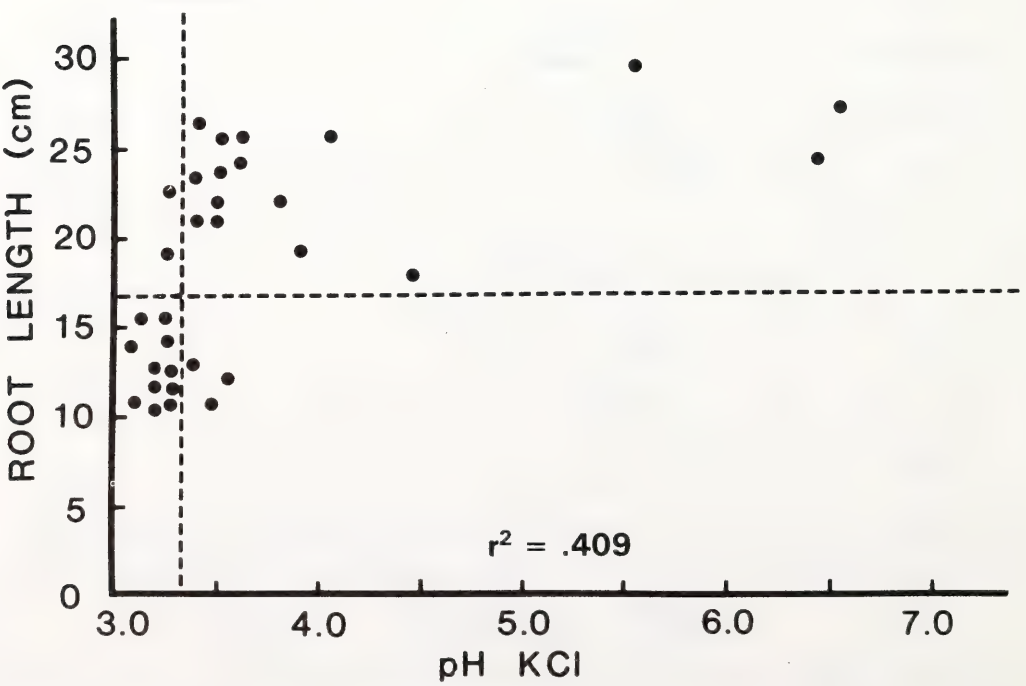

FIGURE 5. *pH in 1N KCl versus root length.*

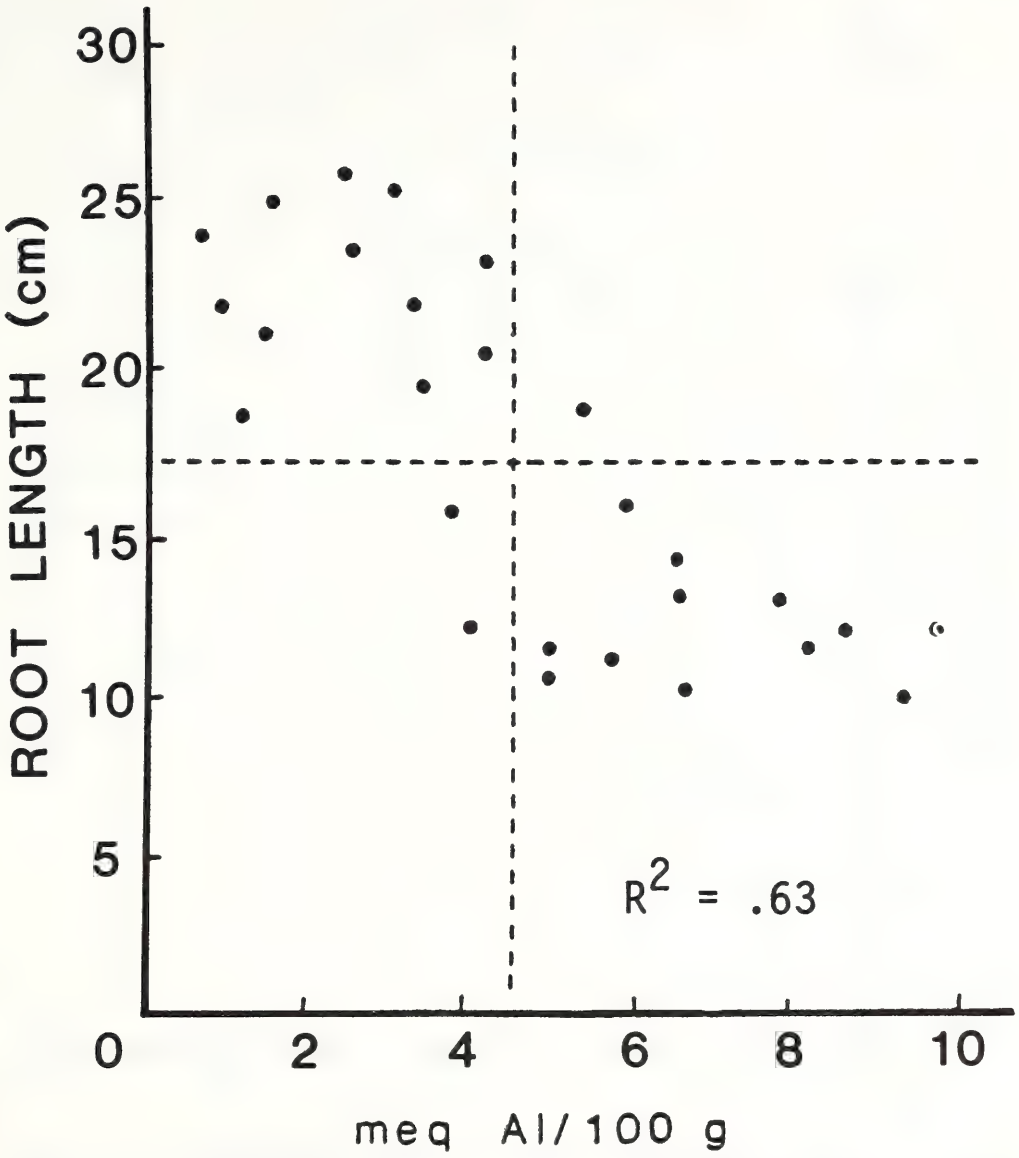

FIGURE 6. *The relationship between exchangeable Al and root length.*

The plot of root growth vs. exchangeable Al gives a fairly definite critical level at 4.5 meq for Abe wheat using the Cate-Nelson technique (Figure 6). Figure 7 shows the relationship of % Al saturation to root growth, and the critical level for toxicity is quite marked at 55%. However, at less than 55% Al saturation there is still much variation in root growth for the various horizons.

Results of our studies support comments by Adams (1983) as there is almost no relationship between pH in water or 0.01M $CaCl_2$ and Al toxicity. In addition there is only a modest relationship between the chemical parameters of pH (KCl), exchangeable Al, percent Al saturation and Al toxicity. The petri dish bioassay is a rapid procedure that bypasses these problems because it is sensitive in detecting Al toxicity directly for a plant genotype on a specific soil. In addition, one can control almost all other factors known to affect root growth, such as soil moisture tension, aeration, bulk density and temperature. The soil's nutrient status, particularly P and K, should not affect seedling root growth, which occurs in the dark, because the energy for growth

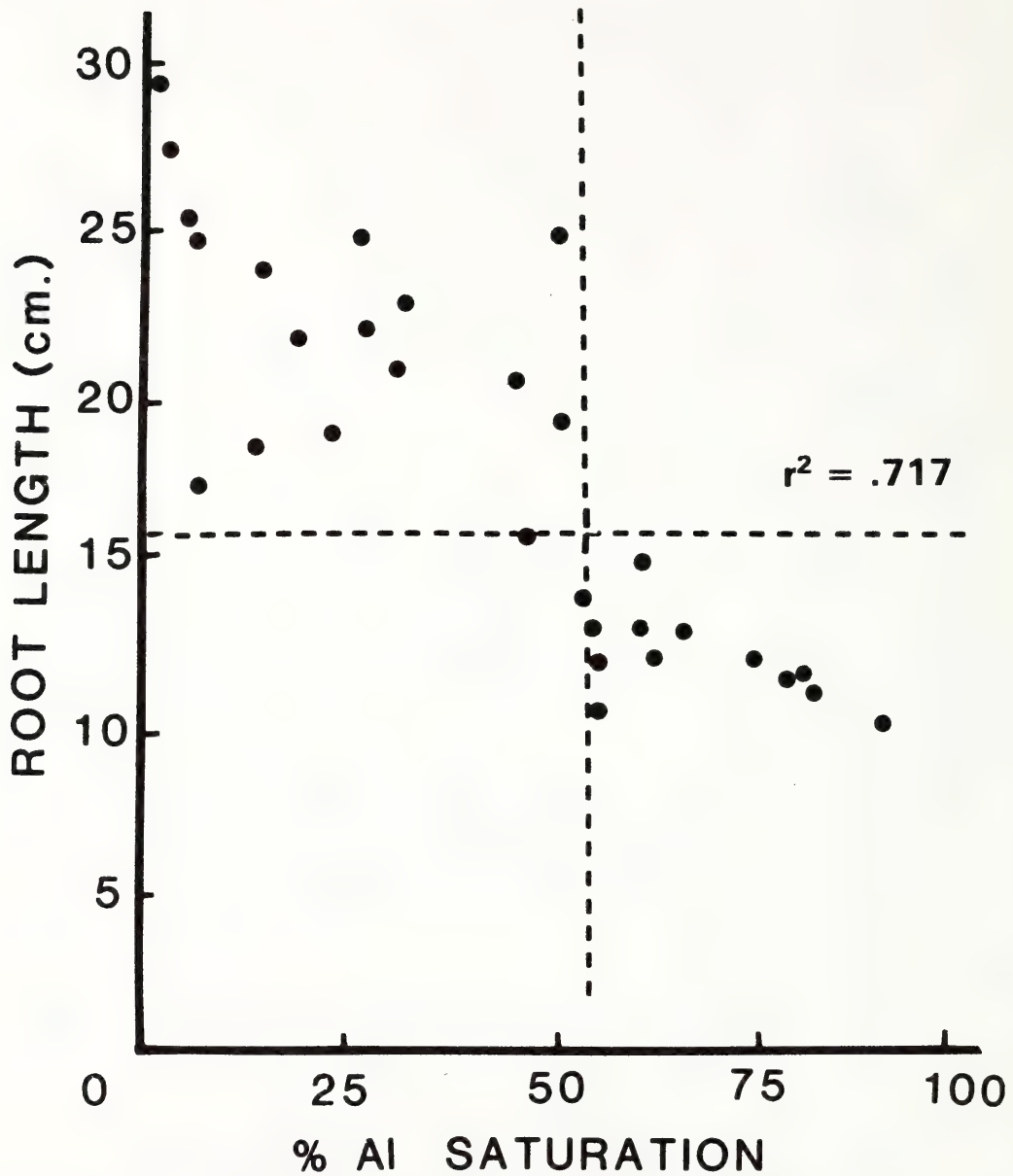

FIGURE 7. *The relationship between % Al saturation and root length.*

is derived from seed reserves and not from the product of nutrient uptake and photosynthesis. Thus, the information gained by this method would help the investigator make sound management or research decisions on acidity problems.

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Nitrification of Ammonium Applied to Soils in Fall, Winter and Early Spring

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Introduction

One of the major problems associated with fall, winter, and early spring applications of ammoniacal fertilizers is the loss of nitrate that occurs following nitrification of added N. Any nitrate present in the profile during the period from March through June has the potential to be lost by leaching (coarse-textured soils) or denitrification (fine-textured soils). Producers are interested in fall and early spring fertilizer applications to avoid excessive work loads at planting time and to take advantage of lower fertilizer prices in the fall. Thus, management procedures that minimize loss of fall or early spring applied N are needed. Two techniques that have been proposed to reduce N losses are: (i) to delay fertilizer application until low soil temperatures prevent nitrification, or (ii) to employ chemicals (nitrification inhibitors) that kill the soil bacteria (*Nitrosomonas* spp.) responsible for ammonium oxidation.

The effect of soil temperature on nitrification is not well defined. Sabey et al. (1956) found that only minimal nitrification occurred when soils were fertilized after soil temperatures had fallen below 10 °C. However, other workers have reported that appreciable nitrification occurred at 7 °C (Frederick, 1956) and some nitrification occurred at 2 °C (Frederick, 1956; Siefert, 1961). Most soil science extension personnel in the Cornbelt recommend that fall application of ammoniacal fertilizers be delayed until soil temperatures decline below 10 °C. However, there is little scientific evidence to support this position. Nitrapyrin [2-chloro-6-(trichloromethyl)pyridine] is a specific and highly effective nitrification inhibitor (Goring, 1962; Huber et al., 1977), however, little is known about the activity of the chemical at low soil temperatures. Therefore, a laboratory study was conducted to define the relationships between cool season temperatures and nitrification in soils in the presence and absence of nitrapyrin.

Materials and Methods

Samples (0-15 cm depth) of two cultivated soils were collected near W. Lafayette, Indiana, air-dried, and crushed to < 2-mm. Chalmers silty clay loam (Typic Argiaquoll) contained 30% clay, 51% silt, 0.20% total N, and 2.60% organic C and had a water pH of 6.8. Fox silt loam (Typic Hapludalf) contained 18% clay, 75% silt, 0.14% total N, and 1.71% organic C and had a water pH of 6.9.

Ten g (oven-dry equivalent) samples of soils were mixed with 30 g of washed quartz sand and added to 225 cm^3 glass bottles containing 4 cm^3 of deionized water. The bottles were covered with 1 mil polyethylene film and incubated without light in a constant temperature cabinet. The temperature was varied throughout the incubation to simulate average long term fall, winter, and spring soil temperatures (10 cm depth) at the Purdue University Agronomy Farm, W. Lafayette, Indiana. Initial starting temperature was 13 °C (simulating conditions on October 15) and the incubation was conducted for 186 days. Termination of the incubation occurred at a spring temperature of 13 °C which simulated conditions on April 20. Different sets of samples

were periodically (10 times during the study) removed, treated with 2 cm^3 of ammonium sulfate solution containing 2 mg of N, and returned to the constant temperature cabinet. Other sets of samples were treated with 2 cm^3 of a solution that contained 2 mg of ammonium sulfate N and 30μg of nitrapyrin. After varying periods of incubation, duplicate samples of treated soils were removed from the incubator and analyzed for ammonium and nitrate by an extraction-distillation procedure (Keeney and Nelson, 1982).

The percent nitrification occurring at varying times after N addition was calculated by the procedure of Bundy and Bremner (1973). The degree-days (DD) that accumulated during an incubation period after N addition were calculated from the equation:

$$DD = \sum_{i=1}^{N} (t \cdot n)$$

where t = temperature during the period
n = number of days in the incubation period
N = number of incubation periods for which DD are accumulated

Nitrification rates were calculated by dividing the amount of nitrate N formed per g of soil by the number of days in the incubation period. All data reported are means of at least duplicate determinations and all values are reported on a moisture-free basis. Values for duplicate samples agreed within ±5%.

Results and Discussion

Table 1 gives data on nitrification in Chalmers soil as affected by N application time and soil temperatures after fertilization. Ammonium added on October 15 (13 °C initial temperature) was almost completely nitrified by Dec. 21. Nitrification of ammonium was 92 and 84% complete by Apr. 20, for ammonium added on Oct. 30 and Nov. 10, respectively. For ammonium additions made between Jan. 1 and Mar. 21, < 17% had nitrified by Apr. 20.

About 54% of ammonium added to Fox soil on Oct. 15 had been nitrified by Apr. 20 (Table2). Nitrification was only 33 and 30% complete by Apr. 20 for am-

TABLE 1. *Effect of soil temperature on nitrification of ammonium added to Chalmers soil*

	Time and soil temperature (°C) when N applied									
Date of sampling[+]	15 Oct 13	30 Oct 10	10 Nov 7.2	28 Nov 4.4	21 Dec 1.7	14 Jan -0.8	4 Feb 1.7	22 Feb 4.4	9 Mar 7.2	21 Mar 10
	% of added NH_4^+ – N nitrified									
30 Oct (10)	34									
10 Nov (7.2)	61	1								
28 Nov (4.4)	88	15	0							
21 Dec (1.7)	98	33	15	1						
14 Jan (-0.8)	—	—	24	16	0					
4 Feb (1.7)	—	—	—	16	0	0				
22 Feb (4.4)	100	77	73	—	0	0	0			
9 Mar (7.2)	—	—	—	30	—	3	—	0		
21 Mar (10.0)	100	85	83	36	7	—	2	1	2	
5 Apr (13.0)	—	—	—	—	—	11	9	4	4	6
20 Apr (15.0)	100	92	84	48	21	16	17	14	16	17

[+] Values in parentheses are soil temperatures (°C) at the end of incubation period.

TABLE 2. *Effect of soil temperature on nitrification of ammonium added to Fox soil.*

Date of sampling [+]	Time and soil temperature (°C) when N applied									
	15 Oct	30 Oct	10 Nov	28 Nov	21 Dec	14 Jan	4 Feb	22 Feb	9 Mar	21 Mar
	13	10	7.2	4.4	1.7	-0.8	1.7	4.4	7.2	10
	% of added NH_4^+ – N nitrified									
30 Oct (10)	13									
10 Nov (7.2)	31	1								
28 Nov (4.4	41	18	0							
21 Dec (1.7)	42	13	4	0						
14 Jan (-0.8)	—	—	11	6	0					
4 Feb (1.7)	—	—	—	7	0	0				
22 Feb (4.4)	73	17	21	—	4	1	0			
9 Mar (7.2)	—	—	—	16	—	2	1			
21 Mar (10.0)	47	28	29	21	—	—	2	2	0	
5 Apr (13.0)	—	—	—	—	—	6	4	5	4	4
20 Apr (15.0)	54	33	30	23	20	11	8	11	12	6

[+] Values in parentheses are soil temperatures (°C) at the end of incubation period.

monium additions made on Oct. 30 and Nov. 10. Ammonium added to Fox soil between Nov. 28 and Mar. 21 was < 23% nitrified by Apr. 20. There was no nitrification in samples of Chalmers and Fox soils treated with ammonium and nitrapyrin regardless of time N was applied or length of incubation following fertilization.

These findings suggest that nitrification occurred in some soils at temperatures near freezing and that a significant potential for loss of fall applied N existed with such soils. However, other soils have low nitrification potentials and only modest amounts of nitrate were formed by mid spring when ammonium was applied at times soil temperatures were < 10°C. The addition of nitrapyrin at 3 μg $g,^{-1}$ of soil completely eliminated nitrification in two soils incubated at temperatures of < 13°C. Therefore, ammoniacal fertilizers can be safely applied in the fall if soil temperatures are < 13°C and nitrapyrin is added. However, significant nitrification may occur in some soils not treated with a nitrification inhibitor even though N applications are delayed until soil temperatures are < 10°C.

Soil temperatures have a marked effect on nitrification rates (Table 3). Nitrification rates of soils incubated at a simulated fall temperature of 10°C averaged 8 and 4 times higher than those of soils incubated at simulated spring temperatures of 10

TABLE 3. *Effect of soil temperature on nitrification rates in two soils.*

Season	Soil temperature	Soil type		
		Chalmers	Fox	Average
	°C	mg NO_3^- – N formed/g/day		
Fall	10.0	3.45	2.09	2.77
Fall	7.2	1.56	0.62	1.09
Fall	4.4	0.90	0.32	0.61
Winter	1.7	0.71	0.30	0.51
Winter	-0.8	0	0	0
Winter	1.7	0.09	0.06	0.08
Spring	4.4	0.27	0.18	0.23
Spring	7.2	0.33	0.31	0.32
Spring	10.0	0.38	0.32	0.35
Spring	13.0	0.87	0.47	0.67

and 13 °C, respectively. Nitrification rates decreased markedly as simulated fall temperatures decreased from 10° to 1.7 °C and no nitrification was measured at temperatures < 0 °C. Increasing soil temperatures from 1.7 to 13 °C during a simulated spring season resulted in increased nitrification rates. However, the nitrification rate at a simulated spring temperature of 13 °C was only slightly higher than the rate at a simulated fall temperature of 4.4 °C.

There were close relationships between the degree-days that accumulated and the amount of nitrate N that formed within a time period when ammomium-treated Chalmers soil was incubated at varying temperatures (Figure 1). However, approximately 7 times more nitrate N accumulated per degree-day with fall applied N as compared to spring applied N. Similar results were obtained with Fox soil. The regression equations for Chalmers soil were:

$y = -48 + 0.36X \qquad r^2 = 0.86$ (Fall applied N)

$y = -4 + 0.05X \qquad r^2 = 0.82$ (Spring applied N)

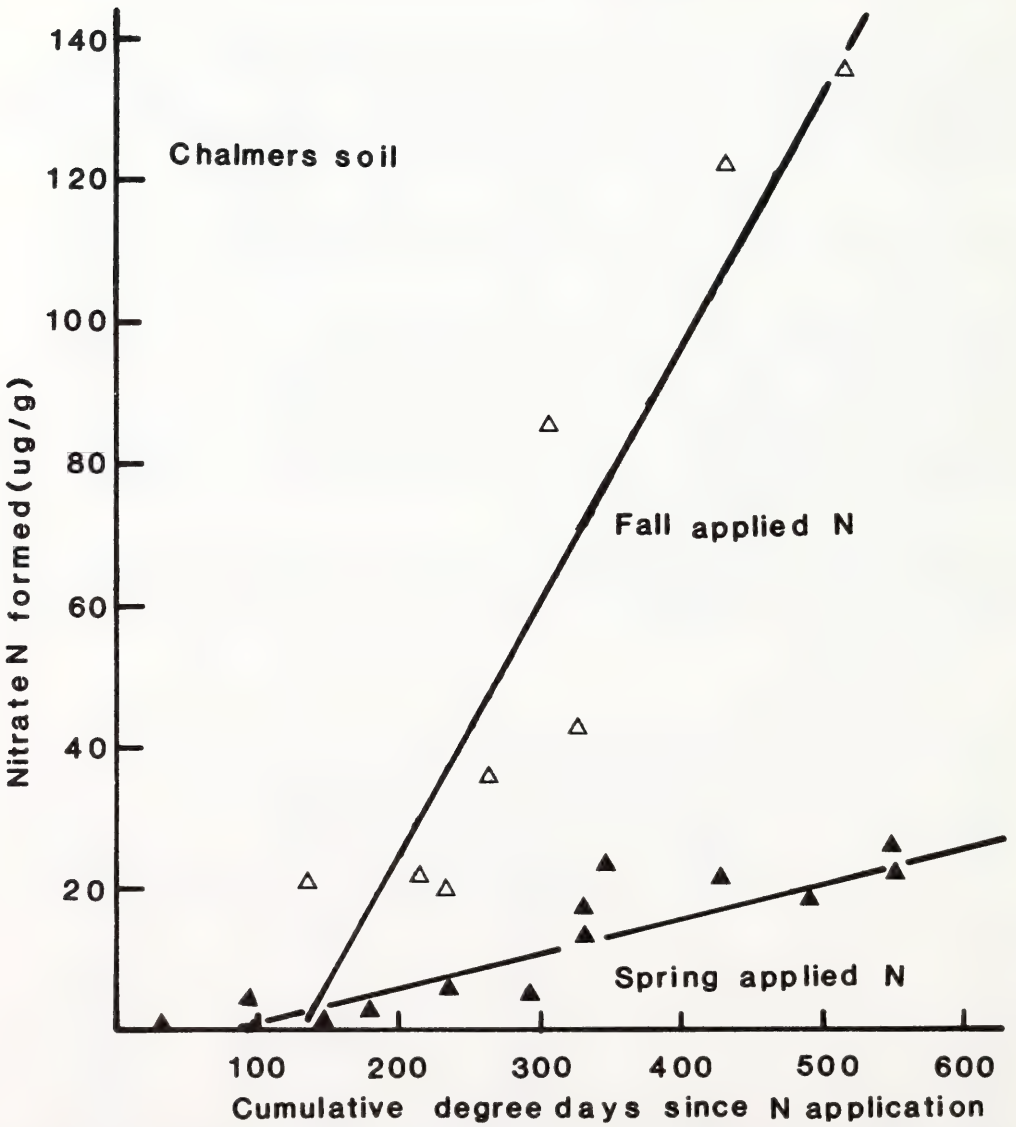

FIGURE 1. *Relationship between nitrate N formed in Chalmers soil and degree-days accumulated during an incubation period.*

The regression equations for Fox soil were:

$y = -19 + 0.14X \qquad r^2 = 0.81$ (Fall applied N)

$y = -1 + 0.03X \qquad r^2 = 0.88$ (Spring applied N)

where y = nitrate N formed in $\mu g\ g^{-1}$ of soil

x = cumulative degree-days in incubation period.

These data indicate that freezing had a profound impact on nitrification in soils. Nitrification rates at a specified temperature were much lower after freezing as compared to those in unfrozen soil. The number of degree-days accumulated per unit of nitrate N formed was much greater for spring applied N than for fall applied N. A possible explanation for these findings is that freezing kills a major proportion of the *Nitrosomonas* spp. in soil and the population expands slowly in the spring because of cool soil temperatures. Campbell et al. (1971) have previously shown that microorganisms present in soils during the fall condition themselves to low temperatures, but soil microorganisms are very sensitive to low temperatures in the spring. These findings suggest that freezing may be a major mechanism for N conservation in soils and that there is little potential for rapid nitrification following ammonium addition to soils in winter or early spring.

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Cold Air Outbreaks over Lake Michigan During the 1982-1983 Winter Season

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Introduction

Shallow convection studies at Purdue University have been focused largely on atmospheric manifestations of Benard-Rayleigh convection, both observationally and theoretically. These studies by the mesoscale-convection group at Purdue have included a considerable effort in identifying related phenomena in real atmosphere events (see Agee and Chen (1); Agee and Lomax (2); Rothermel and Agee (7)). This type of convection is created in the atmosphere by the displacement of cold air masses over relatively large bodies of much warmer water.

A study of such convection was conducted by the Purdue group through participation in the Air Mass Transformation Experiment (AMTEX), a Japanese field program conducted over the East China Sea in 1974 and 1975. In this case, cold Asian air masses would periodically be advected by weather systems out over the much warmer Kuroshio or Japan Current (See Lenschow and Agee (6)). Similar events can occur over the Great Lakes during the winter season. Though there are obvious differences—such as air-sea contrasts ($\triangle T \sim 5\,^{\circ}C$ to $10\,^{\circ}C$ in AMTEX, and as much as $25\,^{\circ}C$ at times over the Great Lakes), longevity of the cold air outbreak (CAO), and the size of the body of water involved (or fetch length)—the objectives and methods of study are similar.

During the winter of 1982-83, a study of CAOs over the Lake Michigan region was conducted. This winter was characterized by abnormally warm temperatures in the Great Lakes region. Figure 1 gives the temperature plot at West Lafayette, Indiana

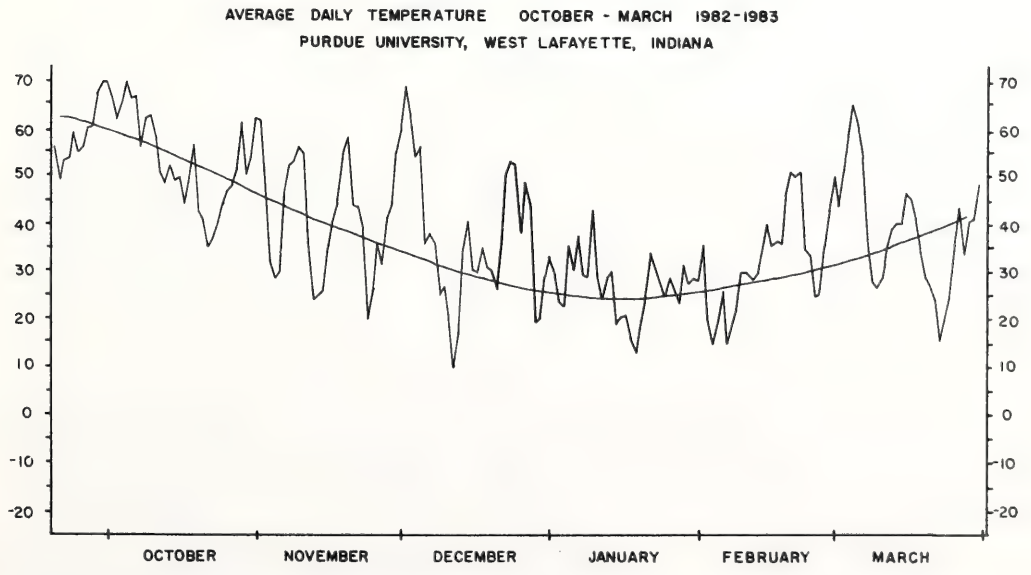

Figure 1. *Average daily temperature for the 1982-83 winter season at West Lafayette, Indiana.*

(approximately 130 km south of Lake Michigan) for October 1982-March 1983, showing above normal temperatures throughout most of the winter season. There were, however, five distinct cold air outbreaks which produced significant lake-effect snow in the Lake Michigan region. An appropriate definition of a cold air outbreak (CAO) might be when the air-water temperature difference is $\geq 5\,°C$. This is consistent with a previous definition and findings by Sheu and Agee (8), Burt and Agee (4), and Agee and Sheu (3); but this will need scrutinizing for Great Lakes events.

Meteorological events produced by a CAO are the formation of convective clouds in a well-mixed boundary layer, which is formed due to strong quasi-uniform heating from below, and perhaps aided to a lesser extent by cold air advection aloft as well as cloud-top radiative cooling. Clouds from this boundary layer in the Great Lakes region are capable of producing measurable snowfall in regions downstream of the lakes. In fact, the areas south and east of the lakes annually received about three times more snowfall than do upwind regions (see Eichenlaub (5)). The lake-effect convective clouds and snow squalls occur in what would otherwise be fair weather dominated by an approaching high-pressure system with cold temperatures following the passage of a synoptic-scale weather system.

Observational studies of the lake-effect snows for each of the five CAOs during the 1982-83 winter season have been conducted. The results from one of these events, namely the 25 February 1983 case, are presented in some detail in this paper. This event was characterized by northerly flow down the main axis of Lake Michigan, with significant snowfall occurring in northwest Indiana. Pertinent surface and upper-air data have been collected and analyzed to determine the manner in which this snow event happened, based on assessment of all possible dynamic and thermodynamic fields (both upstream and downstream). This analysis will show 1) the effect of the lake on the air mass, 2) why the snow occurred where it did, and 3) kinematic and thermodynamic fields producted by the analysis schemes used. These analysis schemes will present both the horizontal and vertical structure of the snow system. The analyses are presented below with a detailed discussion of the results.

Data and Analysis Schemes

Surface data for the 25 February 1983 case study were obtained from the National Weather Service surface hourly reports and the marine coastal weather log for stations in the Lake Michigan region, as shown in Figure 2. A total of 70 weather stations provided the surface data (63 on the map in Figure 2, plus 7 near boundary stations). The analysis scheme used in this study is the Purdue Regional Objective Analysis of the Mesoscale (PROAM). This is a Barnes-type of analysis package implemented at Purdue by Smith and Leslie (9). Using input data of dry-bulb temperature, dew-point temperature, wind speed and direction, and altimeter setting for the reporting surface stations, this analysis package determined distributions of the following quantities: 1) surface streamlines (Ψ_s), 2) geostrophic streamlines (Ψg), 3) pressure field (p), 4) dry-bulb temperature (T), 5) vertical vorticity (ζ), 6) horizontal divergence (D), 7) virtual potential temperature (θ_v), and 8) equivalent potential temperature (θ_e). The domain of the analyzed region was 800 X 800 km, with a square grid spacing of 40 km. The mean grid spacing of the 70 stations used was equal to 63 km.

The upper-air data were obtained from the FAA 604 data circuit, using stations in the rawinsonde network over appropriate regions of the United States and Canada. Two different types of analysis were performed on the upper-air data set. The first scheme generates vertical cross-sections for the virtual and equivalent potential

FIGURE 2. *Locations of 63 of the 70 weather stations used for the surface analyses. (Seven stations, near the boundary, are not depicted.)*

temperature fields. The second was a kinematic analysis of the mesoscale as used by Sheu and Agee (8). This scheme determines localized fields of horizontal divergence, vertical vorticity and vertical motion (ω) using triangular regions for analysis. For this northerly flow case (25 February 1983), the vertical cross-sections were prepared for stations YMO-SSM-GRB-PIA (see Table 1 and Figure 3). The triangular analysis regions

TABLE 1. *Rawinsode stations selected for study of the 25 February 1983 lake-effect snow in northwest Indiana.*

Station Name	Symbol	Latitude	Longitude	Elevation (m)
Moosonee, Ont (CAN)	YMO	50°16′	80°39′	0
Maniwaki, Que (CAN)	YMW	46°22′	75°59′	170
Sault Ste. Marie, MI (USA)	SSM	46°28′	84°22′	221
Green Bay, WI (USA)	GRB	44°29′	88°07′	212
Flint, MI (USA)	FNT	42°57′	83°44′	238
Peoria, IL (USA)	PIA	40°39′	89°41′	201

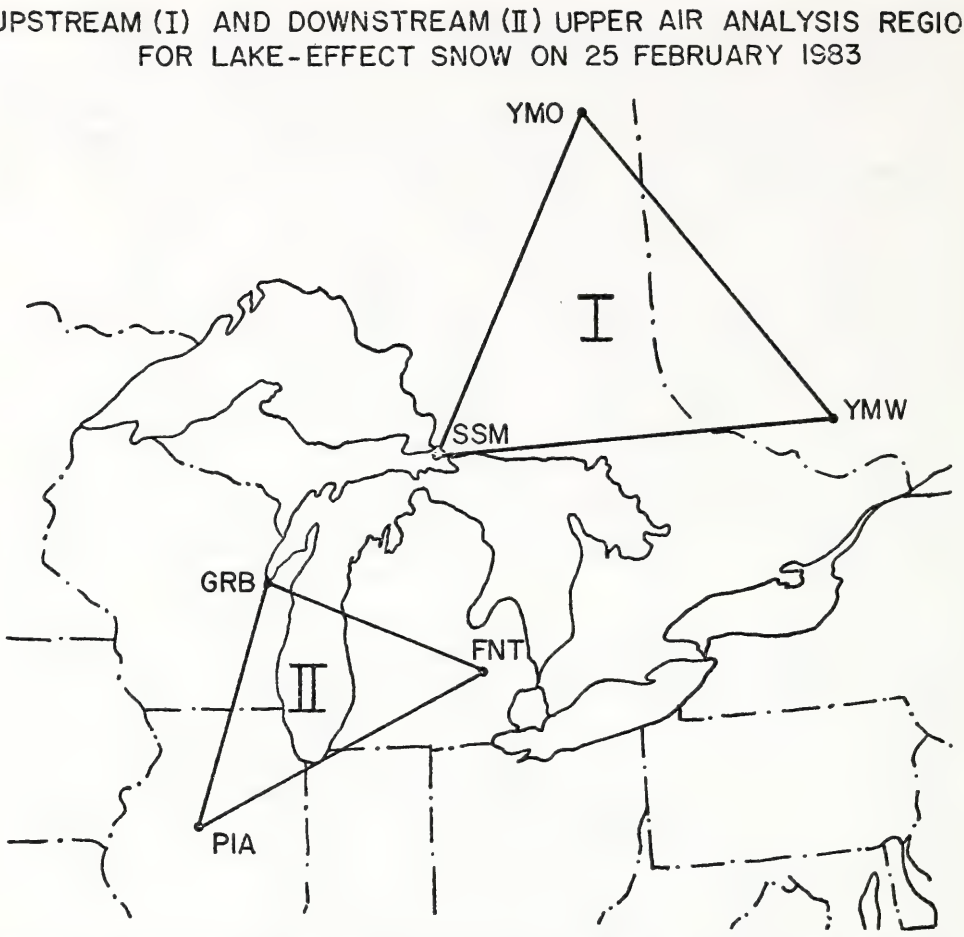

FIGURE 3. *Rawinsonde sites and triangular regions selected for thermodynamic and kinematic analyses.*

selected are shown in Fig. 3, (also see Table 1) with triangle I (YMO-SSM-YMW) designated as upstream region and triangle II (GRB-FNT-PIA) as the modified downstream region.

Other data examined in this study were the surface snowfall reports provided by the National Climatic Center and the 10-cm weather radar microfilm from Marseilles, Illinois (MMO). The analysis of snowfall reports will show the amount of snow that was deposited in the affected area of northwest Indiana. The radar analysis will show the mid-lake cloud band which was responsible for the snow in northwest Indiana.

Synoptic-scale weather conditions for 25 February 1983.

A low pressure center (~1000mb) moving eastward across southern Canada along with a weaker low-pressure system which propagated from South Dakota southeastward through Tennessee brought areas of light rain, snow and fog to the Great Lakes region on 23-24 February 1983. High pressure (~1030mb) moved in behind these systems, bringing cold Canadian air into the Midwest. As this colder air moved across Lake Michigan, a very narrow band of snow developed over the southern end of the Lake Michigan extending into northwest Indiana. At Ogden Dunes, Indiana, located at the extreme southern tip of the lake, 16 cm of snow fell between 0500 GMT 25 February and 0500 GMT 26 February. This narrow band of snow propagated very slowly westward

through the morning of the 25th, with light snow falling in northeast Illinois between 1500 and 2200 GMT before the band dissipated.

The air-lake temperature contrast through this time ranged from about 5 °C to 10 °C, from south to north. By 0000 GMT 26 February, no snow was reported at any station along the southern end of the lake. At this time the high pressure ridge had moved through the Great Lakes, resulting in a shift to southerly flow, breaking up the lake-induced cloud band.

Representative Streamlines for a Convectively Mixed Boundary Layer

The 24-hour snowfall amounts for the period 0500 GMT 25 February to 0500 GMT 26 February and the MMO radar coverage at 1205 GMT 25 February are shown in Figures 4 and 5, respectively. The locations of significant amounts of snowfall

FIGURE 4. *Snowfall amounts (in cm) from 0500 GMT 25 February to 0500 GMT 26 February 1983.*

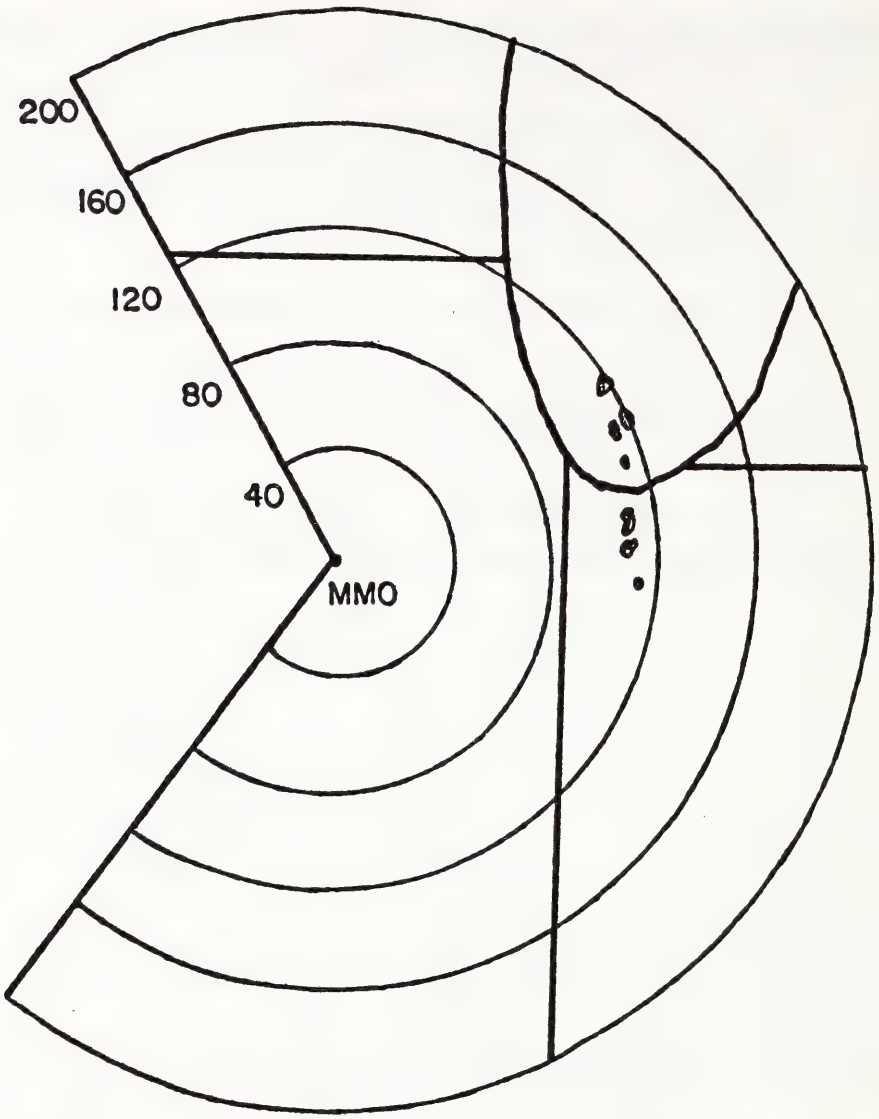

FIGURE 5. *Marseilles, Illinois, (MMO) radar analysis at 1205 GMT 25 February. This is a 10-cm radar PPI pattern with range circles of 40 km radius.*

correspond well with the locations of the radar echoes over the south end of Lake Michigan at 1205 GMT, the time of maximum intensity snowfall during this event. However, the surface streamline pattern for 1200 GMT 25 February, based on surface winds, shows the longest fetch length and landfall of these streamlines to be near the Michigan and Indiana border, east of where the snow is actually falling. Also, the geostrophic streamline pattern, based on the surface pressure field, is not representative of the convective boundary layer (CBL) flow. The geostrophic winds, which were judged to be representative of the flow at the top of the CBL, show a more northeasterly flow across the lake, with the longest fetch length and landfall in northeast Illinois.

Therefore, in the absence of a mesoscale network of rawinsondes over Lake Michigan, it was decided that a resultant streamline pattern would be more representative of the flow through the CBL that produced the lake-effect snowfall in northwest Indiana. By averaging the actual surface winds and the geostrophic winds, the resultant streamline pattern was obtained, which is presented in Figure 6. This pattern, unlike

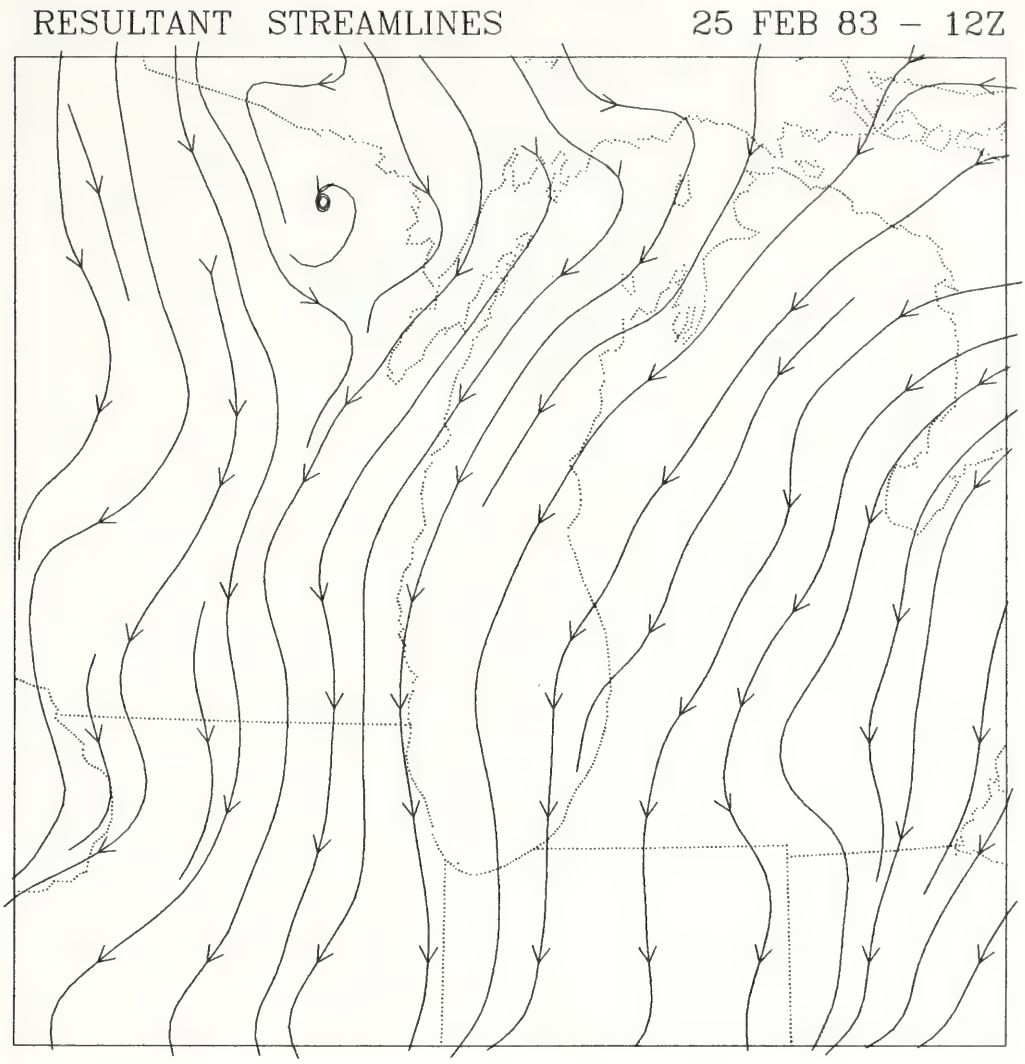

FIGURE 6. *Resultant streamline pattern (derived from surface and geostrophic wind fields) for 1200 GMT 25 February 1983 that represents flow through the CBL.*

the surface and geostrophic streamlines, matches well with the location and alignment of the radar snow band and the snowfall reports in northwest Indiana.

Air Mass Modification (surface analysis)

As previously mentioned, extensive analysis of surface features was performed for this case study using the PROAM scheme. All results presented below are based on the 1200 GMT 25 February 1983 surface data, although analyses were performed for several different times throughout the snow event. The analyses are divided into thermodynamic and kinematic results, which show the effect of the relatively warm water on the cold air which crossed the lake during this event.

a. Thermodynamic analysis

The surface pattern of dry-bulb temperature for 1200 GMT 25 February is presented in Figure 7. The effect of Lake Michigan on the cold air mass is clearly seen in the axis of warm temperatures along the western half of the lake. This matches well with the resultant flow in Figure 6. In the extreme northeast section of the lake, where

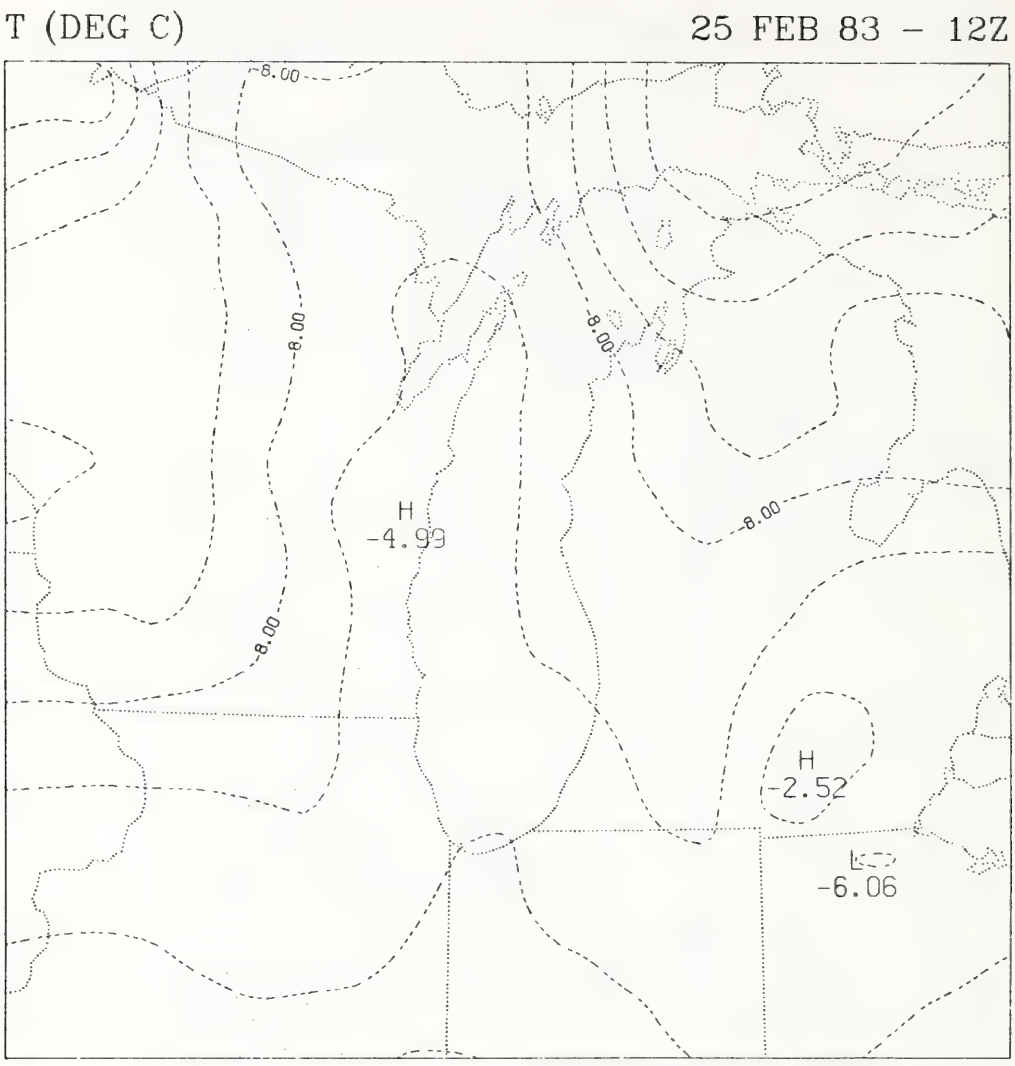

FIGURE 7. *The surface air temperature field at 1200 GMT 25 February 1983, showing the warm axis of modified polar air over Lake Michigan.*

the flow is northeasterly and the air is least modified, the surface temperature is -14 °C. After passing over the warmer lake, the air has become heated over the southern and western part of the lake, with on-shore temperatures >-5 °C. The $\triangle$T across the lake from northeast to southeast is ~10 °C, reflecting the modification process at work. Just 150 km west of the lake, in central Wisconsin, the temperature of unmodified air is <-10 °C. The warming and moistening of the air mass as it crosses the lake could be seen also in the equivalent potential temperature (θ_e) and virtual potential temperature (θ_v) plots, but these are not shown because of their similarity to the temperature plot.

b. Kinematic analysis

The analyses of horizontal convergence and relative vertical vorticity are shown in Figures 8 and 9, respectively. An area of strong convergence (maximum of 5.7 X $10^{-5}s^{-1}$) is centered over the southern half of Lake Michigan. This area is where the most significant convection is ocurring in the boundary layer. The vertical vorticity is also at a maximum over the center of the lake. In both cases, the region west of the lake shows conditions associated with a stable air mass. Strong divergence and negative

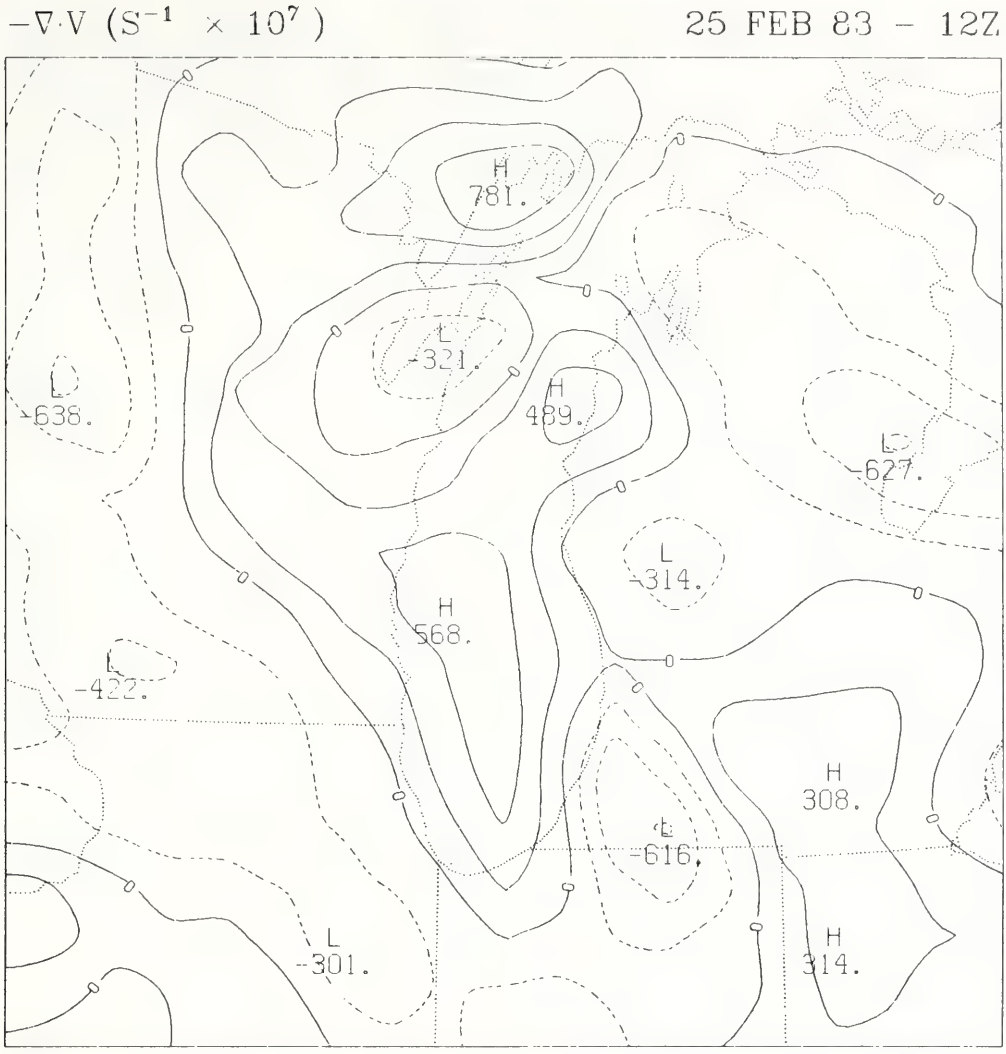

FIGURE 8. *Same as Figure 7, except for the horizontal convergence field ($-\nabla\cdot\vec{\nabla}$). The large (positive) convergence region over Lake Michigan corresponds well with clouds and precipitation.*

relative vorticity are prominent through most of the western half of Wisconsin, in a region unaffected by Lake Michigan.

Air Mass Modification (upper-air analysis)

The upper-air analyses presented below were performed using the 1200 GMT 25 February 1983 rawinsonde observations for the stations mentioned previously. The thermodynamic analysis is a vertical cross-section of virtual potential temperature (θ_v). The kinematic analysis has yielded upstream and downstream analyses of horizontal divergence, relative vertical vorticity and vertical motion. Once again, the modifying effect of the warmer lake is clearly seen in the convective boundary layer, as discussed below.

a. Thermodynamic cross-section

Figure 10 shows the θ_v vertical profile for 1200 GMT 25 February. In the upstream region (YMO and SSM), the air is stable with a rather strong θ_v gradient with height

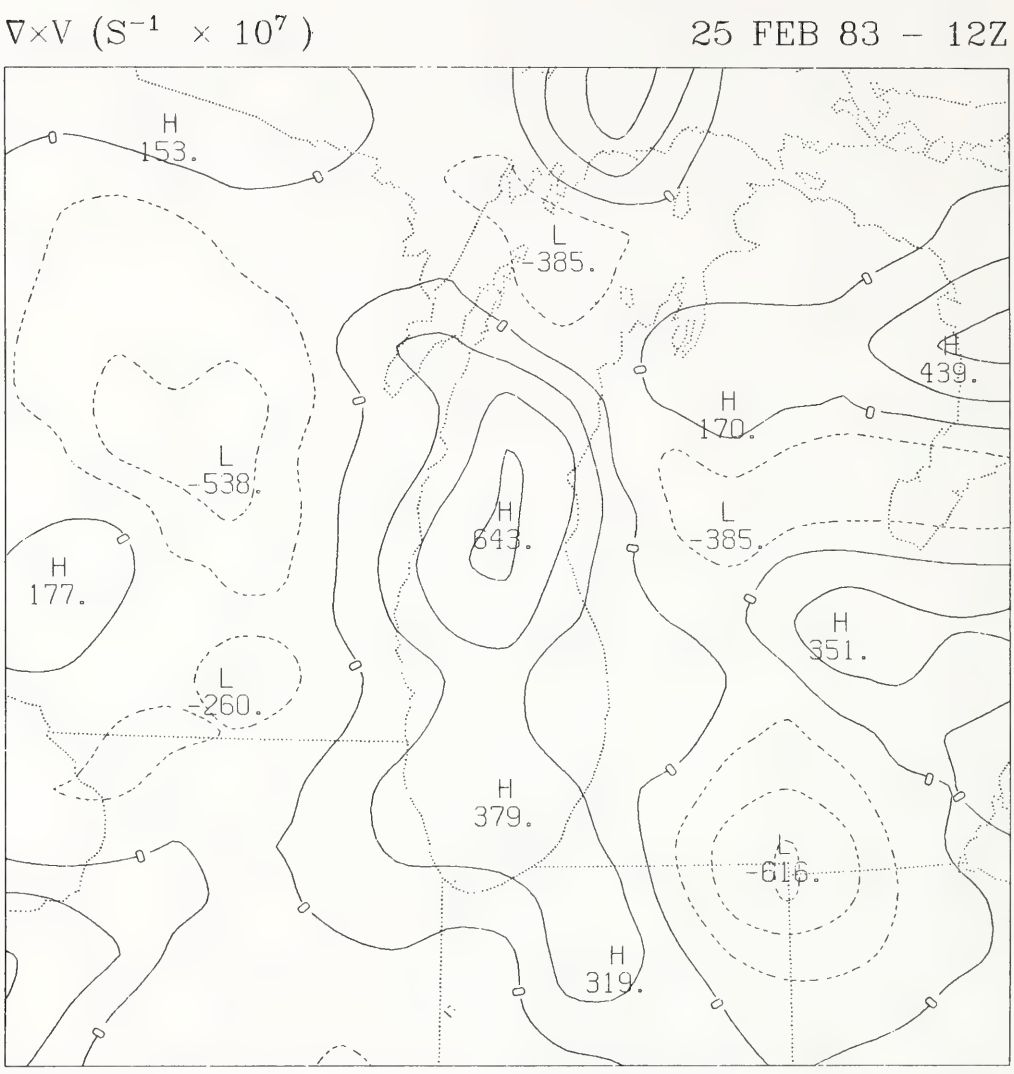

FIGURE 9. *Same as Figure 7, except for the relative vertical vorticity field ($\nabla \cdot X\vec{\nabla}$). Strong cyclonic vorticity is centered over Lake Michigan.*

through the lower troposphere. But in the downstream region (GRB and PIA) the evidence of a convectively mixed boundary layer is apparent. Here the air is almost neutral through the boundary layer, as seen by the very small θ_v gradient up to about 820 mb. At Peoria, Illinois, θ_v increases by just 1.5 °K from the surface to 850 mb, showing downstream effect of a well-mixed convective layer. Upstream of the lake though, at Sault Ste. Marie, Michigan, θ_v increases by 13 °K over the same height, showing a very stable air mass. Above approximately 820 mb, however, the effect of the lake is not too evident, as the θ_v values are very nearly uniform over the entire cross-section. This indicates that convection is occurring only in the boundary layer region, where the lake-effect is present.

b. Kinematic analysis

The comparison of the kinematic variables in the upstream and downstream regions also shows the effect of the lake on the air mass. Figure 11 gives the relative vertical vorticity plot in the upstream region (shown in Fig. 3) while Figure 12 shows the horizontal divergence and vertical velocity (ω) in the same region. All three plots seem to be consistent with earlier observations of strong stability in the region upstream of

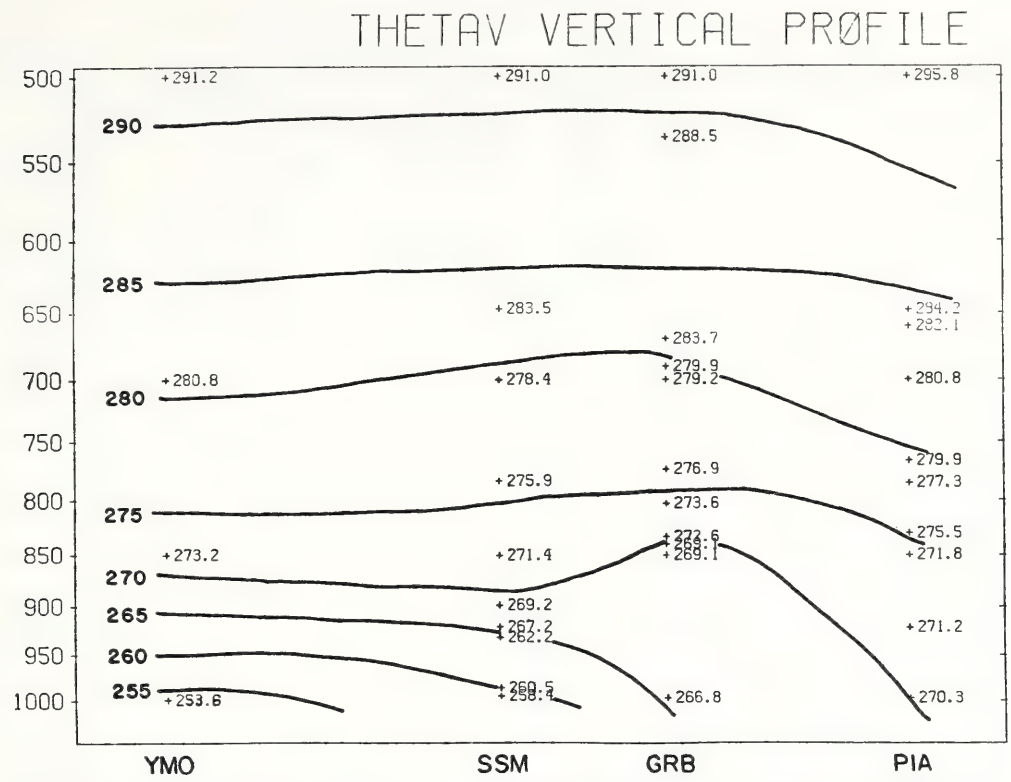

FIGURE 10. *Vertical cross-section of virtual potential temperature (θ_v) at 1200 GMT 25 February 1983, for the stations YMO-SSM-GRB-PIA (see Figure 3 and Table 1).*

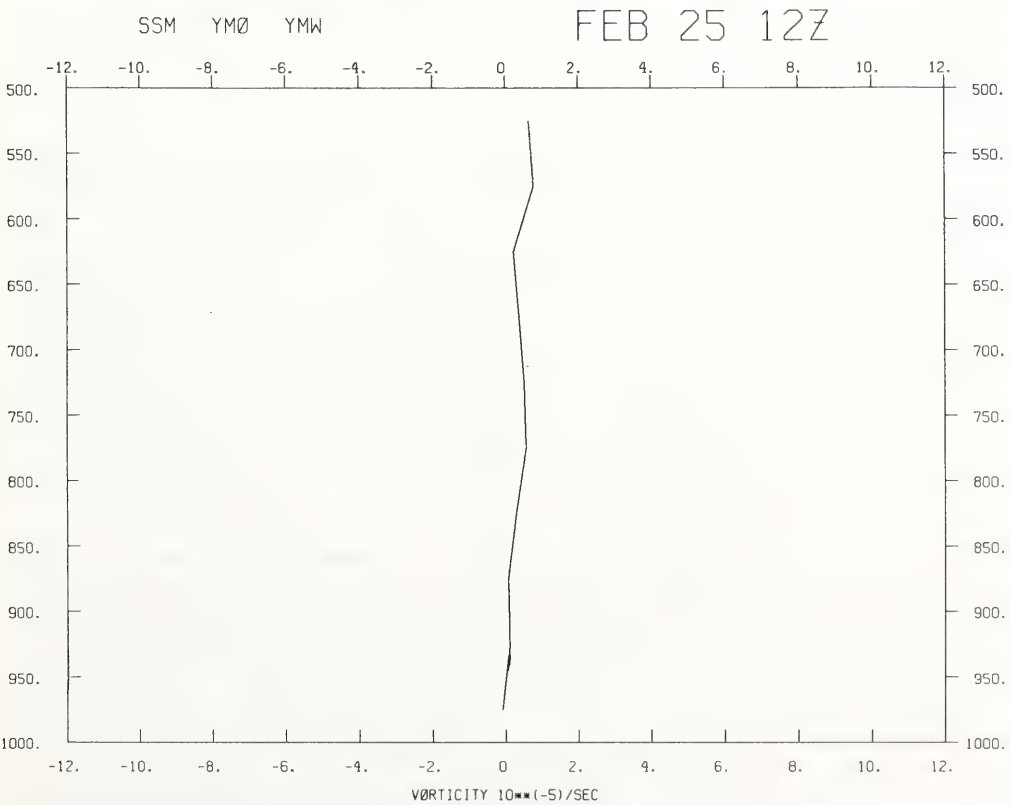

FIGURE 11. *The vertical profile of relative vertical vorticity for the upstream triangle region (SSM-YMO-YNW) of unmodified polar air at 1200 GMT 25 February 1983.*

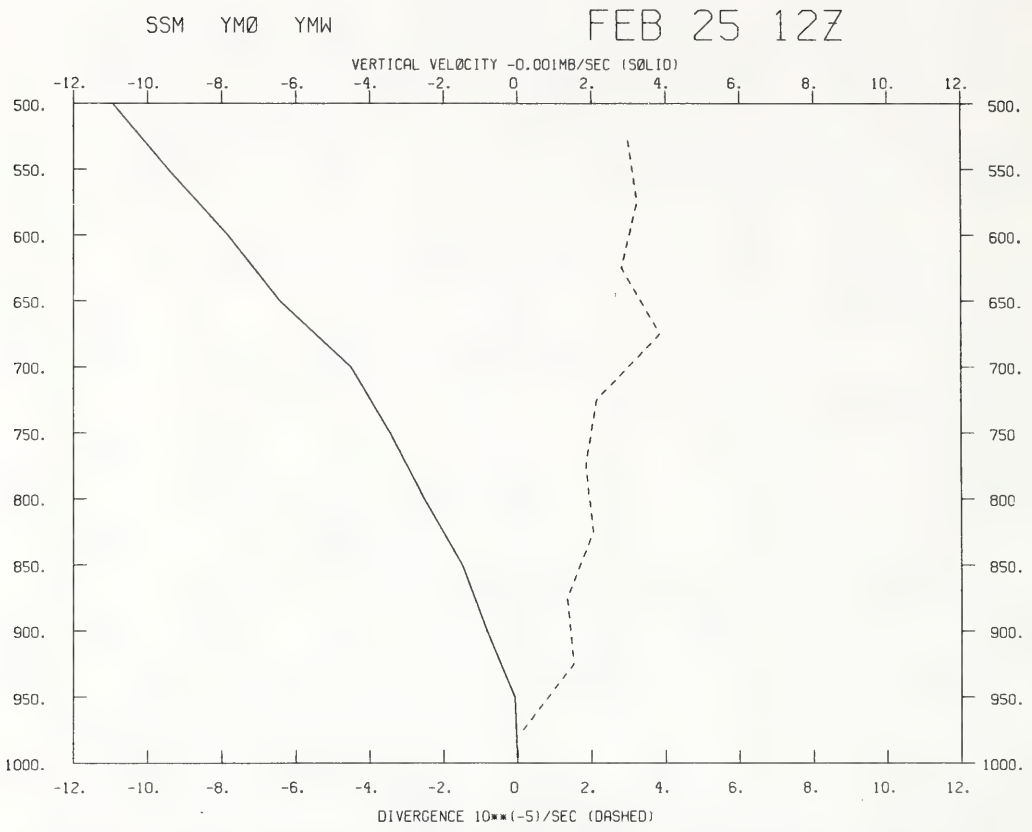

FIGURE 12. *Same as Figure 11, except for vertical motion, ω(solid line) and horizontal divergence (dashed line). The lower half of the troposphere is characterized by a sinking and diverging motion field.*

Lake Michigan. The relative vorticity is negligible through the entire layer (up to 500 mb), downward vertical motion is occurring throughout the same layer, as is positive horizontal divergence. All three of these results show the lower troposphere is under stable conditions, with no convection taking place. Also, no sign of a convective boundary layer is present; however, such is not the case in the downstream region (See Fig. 2).

Figures 13 and 14 give the plots of vertical vorticity, horizontal divergence and vertical motion downstream of Lake Michigan. The values of relative vorticity are significant throughout the entire lower troposphere. In this case there is little indication of a convective boundary layer, although the values of vorticity have been increased substantially. By studying the horizontal divergence and vertical vorticity plots (Figure 14), the presence of a convective boundary layer is clearly seen. Upward vertical motion is occurring up to approximately 800 mb, and negative values of divergence (or convergence) are present up to about the 825-mb level. These two results support the earlier statement that convection is taking place in the boundary layer up to about 820 mb. Above this boundary layer, stable conditions again seem to prevail with positive horizontal divergence and downward vertical motion present.

Summary and Conclusions

A resultant stream field was determined to obtain a representative flow in the convective boundary layer over Lake Michigan during a cold air outbreak. This resultant

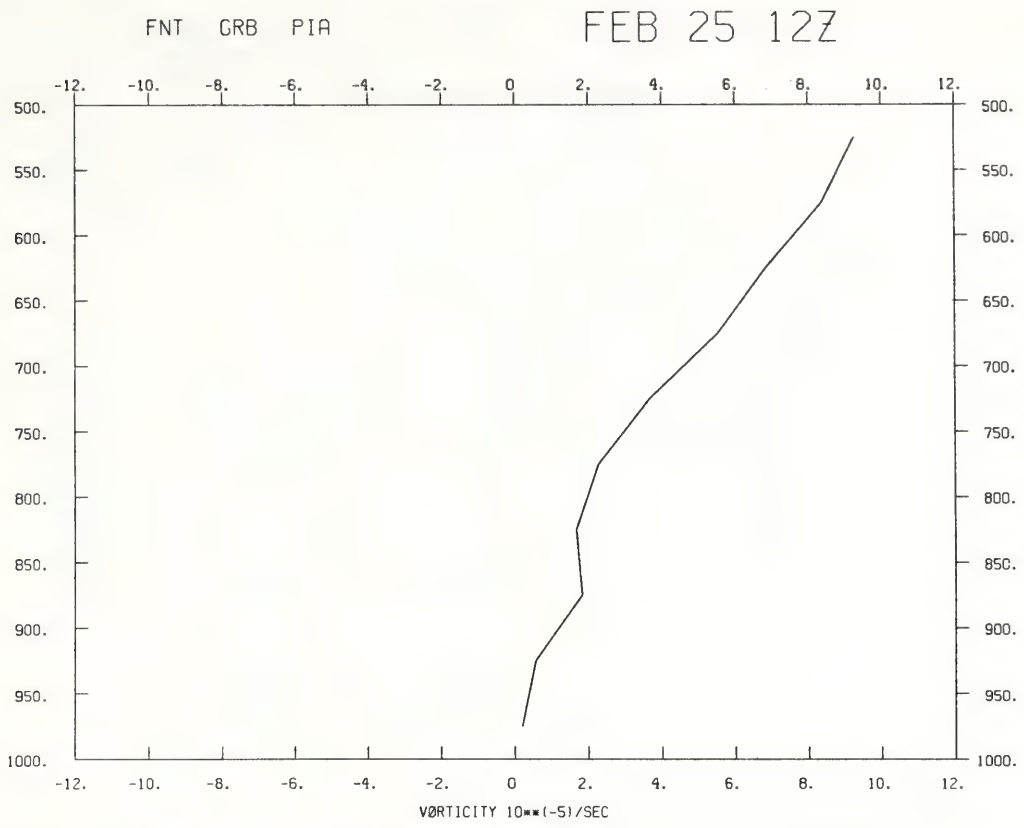

FIGURE 13. *The vertical profile of relative vertical vorticity for the downstream triangle region (FNT-GRM-PIA) of modified polar air at 1200 GMT 25 February 1983. Comparison of Figures 11 and 13 shows a strong increase in cyclonic vorticity.*

was obtained by averaging the surface winds and geostrophic winds (based on surface pressure) and was found to be more representative of flow throughout the convective boundary layer than either of its components.

Surface and upper-air analyses presented have also provided further quantitative information on the 16 cm lake-effect snow that occurred in northwest Indiana on 26 February 1983. Lake Michigan appears to have warmed the cold air mass by some 10°C at the surface. The lapse rate was modified from strongly stable to almost neutral, while the horizontal wind field changed from sinking and diverging flow to converging and rising motion over Lake Michigan and points downstream. The vorticity field also was altered significantly, changing from almost zero relative vertical vorticity to values in excess of $5 \times 10^{-5} s^{-1}$. The addition of both heat and moisture from the lake was shown also in the θ_e and θ_v fields (for both surface and upper-air analyses).

The University of Chicago Cloud Physics Group and the Purdue Mesoscale Convection Group will be combining their interests (in collaboration with the National Center for Atmospheric Research, NCAR) to undertake an extensive field study of lake-effect convective systems due to CAOs over Lake Michigan. This field program, scheduled for Lake Michigan from 1 December 1983 through 28 January 1984, will allow for a more in-depth study of phenomena associated with the lake-effect snow storms. Special rawinsonde observations will be taken daily at Muskegon, Michigan, on the east shore of Lake Michigan (by the Chicago group), and at the Indiana Dunes National Lakeshore Headquarters in Porter, Indiana, located at the extreme southern end of the lake (by the Purdue group). These observations will conceivably give more detailed downstream and cross-sectional analyses for the upper-air analysis packages.

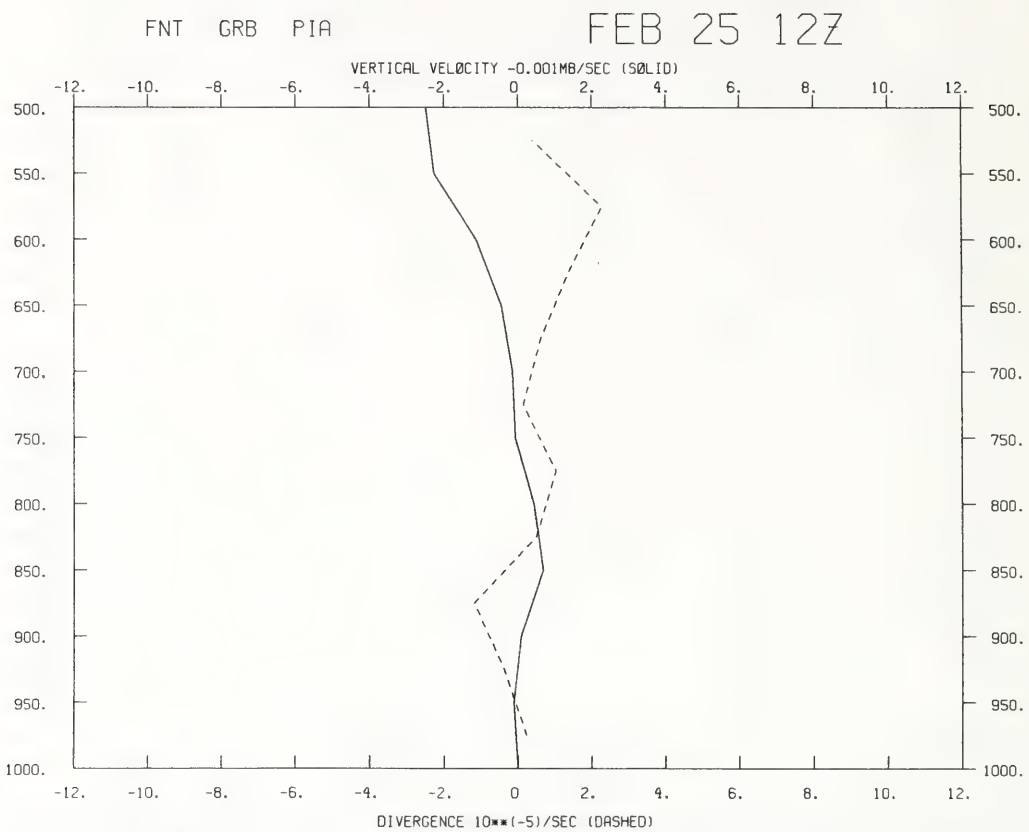

FIGURE 14. *Same as Figure 13, except for vertical motion, ω(solid line) and horizontal divergence (dashed line). Comparison of Figures 12 and 14 shows that the modified air has developed a boundary layer of converging and rising motion, a transformation from the upstream condition of stable, sinking and diverging flow.*

The PAM II mesonet system which will be deployed around the lake will allow also for a denser network of surface observations in the Lake Michigan region, thereby giving a more representative picture of mesoscale conditions.

Acknowledgments

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Determination of Error for the Purdue Regional Objective Analysis of the Mesoscale (PROAM)

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Introduction

Objective analysis of data is the utilization of a mathematical algorithm to interpolate values of measured variables onto a uniform network of grid points. Such interpolation schemes have proven to be very useful tools for processing meteorological data, since meteorological observation sites are not uniformly distributed in space. The input for the objective analysis scheme is the routinely measured meteorological variables (temperature, dew point temperature, pressure, winds, etc.) from stations located nonuniformly throughout a region. The mathematical algorithm then generates as output these measured variables at regularly spaced grid points. The analysis process is greatly facilitated since computerized graphics routines can assist in the display of such data fields. Furthermore, derived quantities such as divergence and vorticity can also be computed. There are numerous examples in the literature where researchers make use of such objective analysis schemes to diagnose siginficant meteorological events.

One of the more commonly used objective analysis algorithms in meteorology is one developed by Barnes (1,2). This scheme applies a Gaussian weighting function

$$W_{i,j,k} = \exp\left(-\frac{R_{i,j,k}^2}{\alpha}\right) \quad (1)$$

to a set of observations (Q_k) to compute an interpolated value ($Q^*_{i,j}$) at each grid point [$R_{i,j,k}$ is the distance between the grid point (i,j) and the station (k) involved in each interpolation.] Barnes has shown the response for such a weighting function in dependent upon a filter parameter (α) and the wavelength (λ) that is being resolved by the data.

A variation of the Barnes scheme, referred to as PROAM (Purdue Regional Objective Analysis of the Mesoscale) has been developed for analysis of surface data over a regional area. This version of PROAM is a modified two-pass Barnes (2) scheme, in which an initial analysis of the data is corrected by making a second pass with the algorithm in order to reduce deviations between observed and interpolated values at each station. PROAM has proven to be an effective tool for the diagnosis and nowcasting of severe convective events [Snow *et al.*, (5); Smith and McCauley, (4)]. While such schemes as PROAM can be very useful, there are some problems which must be addressed in order to adequately determine its capability as a reliable analysis tool.

One of the matters that must be considered is a determination of the error limits associated with the algorithm employed by PROAM. In particular, how effectively does the algorithm, which interpolates the data to the grid points, reproduce the meteorological phenomena resolved by the data? Since surface meteorological features are rather complex due to the interaction of several scales of atmospheric disturbances, it is somewhat difficult to quantitatively establish error limits. Smith and Leslie (3) have performed error analyses for PROAM using analytic distributions typical of atmospheric temperatures. They computed average grid point errors (the mean deviation between the known analytic solution and the interpolated values from the gridded field) for a variety of analysis parameters. They found that this Barnes-type scheme could produce analyses of surface data with average grid point errors on the order of 0.5 °C, which is consistent with errors of measurement for temperature. One of

their findings, however, demonstrated that part of the error in the analysis could be due to the location of the stations which influenced the interpolation for the grid point value. For example, if all stations that significantly contribute to a grid point value are located south of this point, one would expect a bias toward warmer temperatures at that location. An examination of any surface weather map reveals that weather stations are scattered nonuniformly throughout space, with clusters of stations near large metropolitan areas and large data void regions in rural areas. Such a station distribution tends to complicate the analysis because it is difficult to discriminate the error due to the algorithm from that associated with irregular station spacing. This study addresses the problem of error determination due to station location.

Objective and Methodology

The objective of this investigation is to determine error limits associated with PROAM without the additional complication of irregular station spacing. Following the technique of Smith and Leslie (3), analytic functions (Figure 1) were selected to

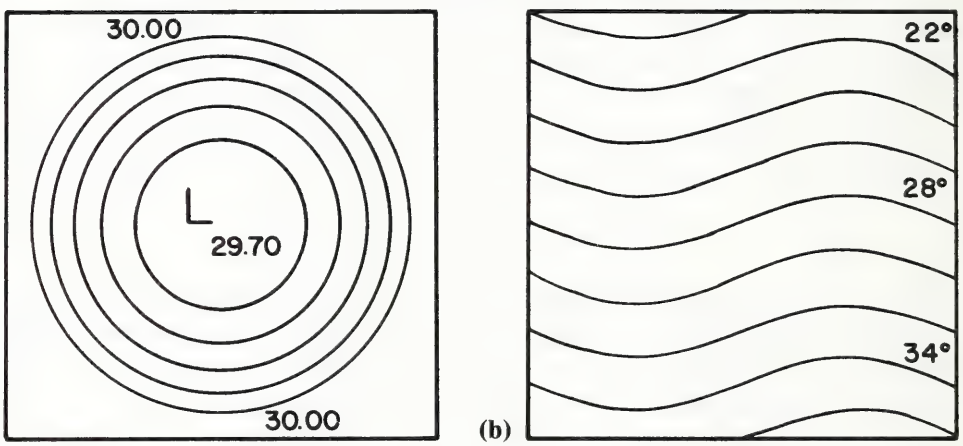

FIGURE 1.

a) Analytic function for pressure, with a contour interval of 0.05 *in. Hg.*

b) Analytic function for temperature, with a contour interval of 2 °C.

generate the data set used by the algorithm. However, rather than using actual surface station locations, the values were assigned to a uniformly distributed set of locations, (referred herein as "data sites"), then PROAM interpolated this data set onto a uniform network of grid points that is staggered from the station network. Root-mean square (RMS) and average grid point (AGP) errors were then computed for a variety of experiments. These errors can give guidance to the user, permitting a judicious choice of the analysis parameters which will minimize the errors associated with the scheme.

Several experiments were conducted to generate error (RMS and AGP) curves for the important analysis parameters used by PROAM. These parameters include a filter parameter (α), radius of influence (R_{inf}) and wavelengths (λ_T, λ_p) of the disturbances which are being resolved by the scheme. The filter parameter determines the degree of smoothing performed by the weighting function $W_{i,j,k}$. As α increases one expects greater smoothing of extreme data points in the analysis. The radius of influence (R_{inf}) determines the area surrounding each grid point from which data sites are selected to perform the interpolation. As R_{inf} increases, a greater number of data sites will con-

tribute to the grid point value. The wavelengths (λ_T, λ_p) determine the scales of the disturbances to be resolved. The analytic temperature function (Figure 1) is a simple sinusoidal wave, while the pressure function is a circular pattern. By decreasing the wavelength, the frequency of occurrence of the waves is increased throughout the domain. The results presented show the effect of these parameters on the analysis, particularly the error distributions associated with variations of these parameters.

Results and Discussion

A series of experiments was conducted using PROAM in which one of the significant analysis parameters was allowed to vary through a range of values while holding the other parameters constant. The control conditions used in these experiments were $\alpha = 0.6\ cm^2$, $R_{inf} = 1.0$ cm, $\lambda_T = 10$ cm, $\lambda_p = 20$ cm. (The units represent length as depicted on the map plane of the analysis. Since the maps are scaled by 10^{-7}, 10 cm corresponds to 1000 km, which is the actual distance across the domain of the analysis region.)

Experiment 1: Variation of α (0.1 - 4.8 cm^2)

The filter parameter (α) controls the degree of smoothing produced in the analysis of the data, whereby greater detail is generated for smaller values of α. One might expect the greater detail in the analysis would imply higher accuracy. The RMS error, which is actually a measure of the fit of the interpolated fields to the original data, is shown in Figure 2a. Note that RMS error increases monotonically over the range

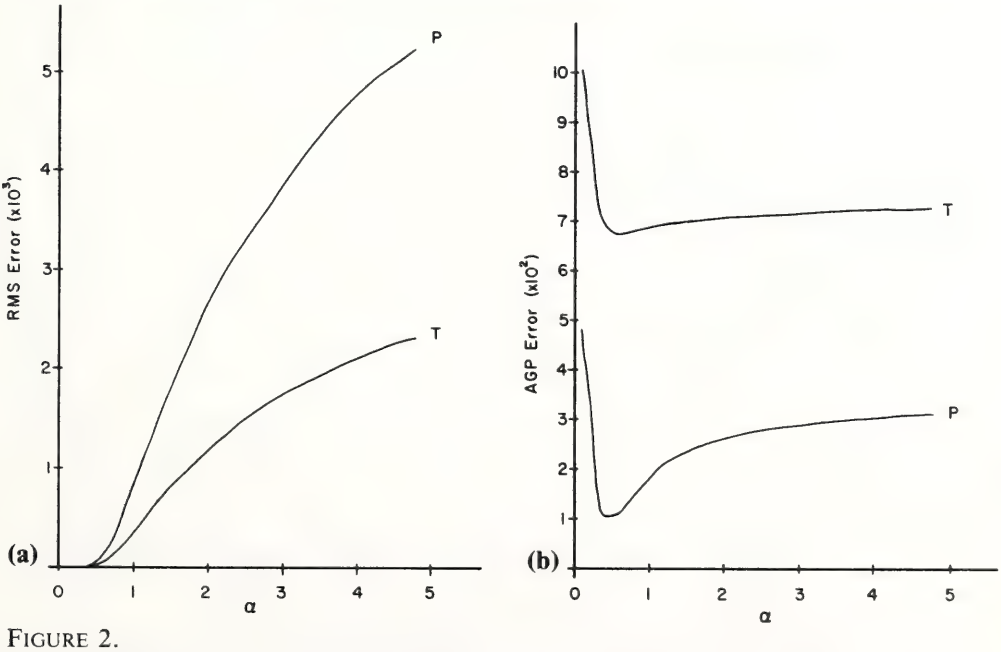

FIGURE 2.

a) Root mean square error of pressure (p) and temperature (T) functions with respect to the filter parameter (α).

b) Average grid point error of pressure (p) and temperature (T) functions with respect to α.

[*Error has been normalized by $A_x^{1/2}\ A_y^{1/2}$, where A_x is the amplitude of the wave in the X-direction (East-West) and A_y is the amplitude of the wave in the Y-direction (North-South).*] α is expressed in units of cm^2.

of α values. This indicates that additional smoothing, which reduces the effect of extreme values, produces an analysis that is less representative of the actual data. In other words extreme high and low observations have been modulated by values closer to the mean value of the field. The average grid point error (Figure 2b) however, shows that perhaps the analysis using smaller α values is questionable. Size less smoothing occurs, the contribution of shorter wave features is enhanced. Actually, these higher frequency waves are noise rather than significant features in the analysis, thereby producing larger errors in the analysis. A minimum in AGP error is apparent for $\alpha \sim 0.6$, with a slight increase in error for larger α values (effect of smoothing). This value of α corresponding to the minimum AGP error then suggests an optimum choice for α for the analysis. Determining an optimum α value thus provides the analyst with an effective selection criterion for the filter parameter.

Experiment 2: Variation of R_{inf} (0.5 - 4.0 cm)

The radius of influence controls the number of data sites influencing the interpolation at each grid point. For small R_{inf} values there is a higher probability of a single data site contributing to the interpolation, thereby introducing a bias in the analysis. This possible source of error is reduced for larger areas of influence, since multiple data sites contribute to the analysis. Figure 3a shows the RMS errors as a

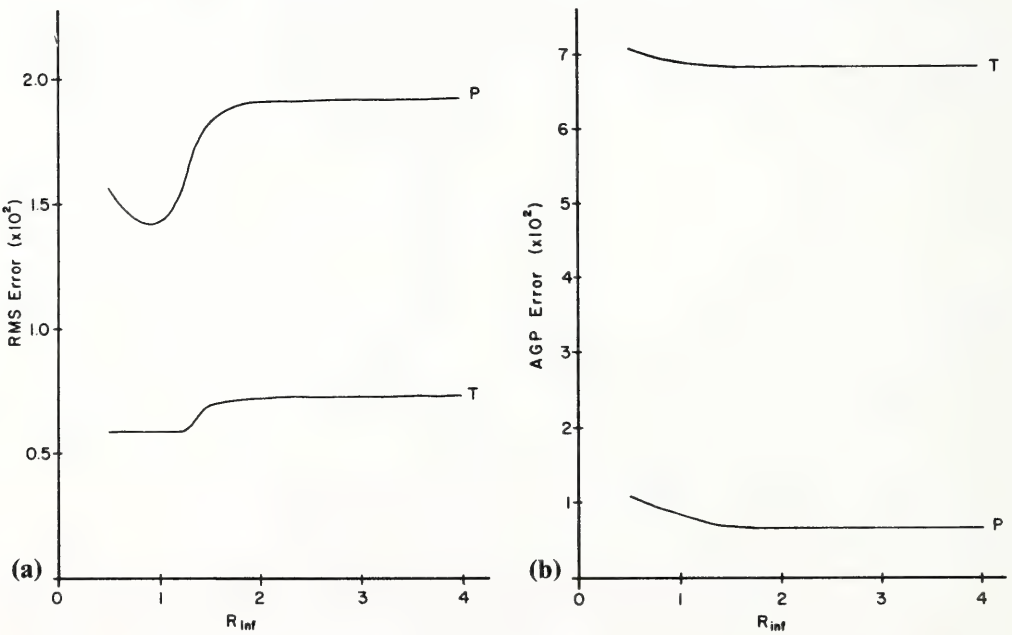

FIGURE 3.

a) Same as Figure 2a, except with respect to the radius of influence (R_{inf}).

b) Same as Figure 2b, except with respect to R_{inf}.

R_{inf} expressed in units of cm (distance as measured on the map plane).

function of R_{inf}. As expected, the P-curve shows an initial decrease in error as R_{inf} increases to 1. RMS error then increases for $1.0 \lesssim R_{inf} \lesssim 1.5$. This can be explained since the algorithm is selecting data sites further from the analyzed grid point to contribute to the interpolation. Since the analytic functions determine the observations for each data site, as we progress farther from the grid point, there is a greater deviation for these contributing data sites values from the value at the grid point, so error

increases. Beyond a certain radius ($R_{inf} \geq 2$) the contribution of these data sites is minimal (since the weighting function decreases exponentially with R^2), hence the RMS error levels off to a constant value. The average grid point error (Figure 3b) does show a gradual decrease in error as R_{inf} approaches 1.5. These error curves also show the same asymptotic behavior as RMS error at larger R_{inf}. Since larger R_{inf} increases the computational run time for PROAM, there is no real benefit, in terms of error reduction, to increasing R_{inf} beyond 1.5. Therefore, an optimum range of values for R_{inf} is 1.0 to 1.5 for this data set and data site distribution.

Experiment 3: Variation of λ (2-10 cm)

Since the response for the weighting function increases with λ, one would expect a better analysis for longer wavelength phenomena. Both RMS and AGP error analyses verify this (Figures 4a and b). In both sets of curves error decreases dramatically (for $\lambda < 5$) with an increase in λ, while at longer wavelengths there is little reduction in error. Since the response at $\lambda = 2$ cm (for $\alpha = 0.6$) is 80%, and it is nearly 99% for $\lambda > 5$ cm, one would expect to be able to resolve the smaller wavelengths with less accuracy than longer wavelengths. Furthermore, there is less significant improvement for $\lambda > 5$ cm.

Conclusions

This investigation has determined error limits for the PROAM scheme for analytic functions representative of surface temperature and pressure. This study used a uniform network of data sites in attempt to remove the effect of clustering and data void areas from the analysis. The major findings were:

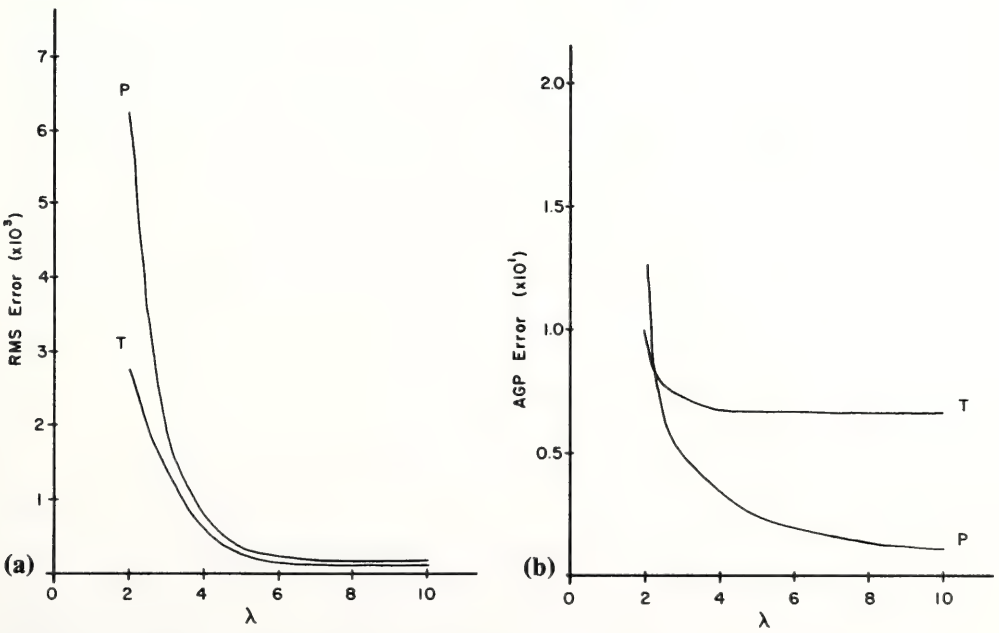

FIGURE 4.

a) Same as Figure 2a, except with respect to wavelength of the analytic functions (λ_p, λ_T).

b) Same as Figure 2b, except with respect to λ_p, λ_T.

λ *expressed in units of cm (distance as measured on the map plane).*

1) An increase in α produces larger RMS errors;

2) An optimum α value exists to minimize both RMS and AGP errors;

3) An optimum R_{inf} range exists to minimize errors;

4) Error reduction for R_{inf} does not justify additional computional run time; and

5) Error decreases as the wavelength of the disturbance increases.

Future work will involve a comparison of these results for a uniform data site distribution with that of a non-uniform station distribution typical of actual conditions.

Acknowledgments

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Crust Strengths of Two Indiana Soils as Influenced by Soil Properties and Tillage

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Introduction

Soil crusting reduces plant emergence (Taylor, 1962), and is a significant problem on many Indiana soils. Careful examination of the characteristics of soils that lead to crusting is needed before appropriate practices to control crusting can be devised. Crust strength is affected by soil moisture content, organic matter content and other factors. The effect of the crust on seedling emergence is also affected by the crop and size of the seed (Arndt, 1965a & b; Parker and Taylor, 1965).

Penetrometers have normally been used to measure crust strength in the field. Brossman *et al.* (1982) demonstrated an alternate technique that worked well under greenhouse conditions. It has the advantage over penetrometers of measuring the pressure required to break through the crust from below, and the disk used was similar in size to a soybean seed.

Materials and Methods

Two soils on the Purdue University Agronomy Farm near West Lafayette were studied. The soils were divided into three conditions based on drainage and landscape position. Condition I was a poorly drained Chalmers soil in a depression landscape position. It is classified as a fine-silty, mixed, mesic Typic Haplaquoll. Condition II was also a Chalmers, but better drained and transitional to Condition III. Condition III was a somewhat poorly drained Raub soil on a landscape swell position. It is classified as a fine-silty, mixed, mesic Aquic Argiudoll. The Chalmers soils have a silty clay loam to silt loam surface texture characterized by a coarse granular structure and a high organic matter content (4.8-6.4%). The somewhat poorly drained Raub soil has a silt loam surface texture and differs from a Chalmers soil in having a lower organic matter content (2.6-3.8%).

Experimental Design

The field was divided into 18 plots each 9 m. x 29 m. Each soil condition was represented by six plots.

Following fall plowing, the plots within each soil were randomly assigned either zero or one or two disk harrow treatments as spring secondary tillage. The disk harrow treatments were then split with each plot randomly assigned either zero or one power harrow treatment. There were six possible treatments, replicated twice, within each soil condition.

All plots were fall plowed with a moldboard plow and disk harrowed with a light 15 foot finishing disk. A 10 foot Neimeyer TE 300 oscillating power harrow was used for the power harrow treatment. A John Deere max-emerge planter was used both years for planting.

Becks 65X (MO 17 x B73 single cross) corn (Zea Mays) was planted May 9, 1980 at a population of 65,000 Seeds/ha. Nitrogen at a rate of 280 kg/ha was applied as anhydrous ammonia (NH_3).

In 1981 each treatment was prepared as in the previous year and planted to Century soybeans (Glysine max) on May 29, at 55 kg/ha.

Laboratory Analysis

Bulk density (coated clod method) and the particle size distribution procedures were those of the Purdue University Soil Characterization Laboratory (Franzmeier, *et al.*, 1977). The mean weight diameter of water stable aggregates was measured according to Yoder's method (Kemper and Chepil, 1965). All samples were taken at a depth of 0-8 cm.

Field Measurements

Within each half plot two 5.3 meter sections in two different rows were marked on the day of planting and plants were counted each day thereafter to obtain emergence data.

Crust strength was measured by burying five 1.2 cm diameter buttons in the two center rows of each split plot. Each button was planted approximately 1.3 cm. deep by first making a hole 2.5 cm. in depth and slipping the button sideways into the adjacent undisturbed soil so it was firmly imbedded 1.3 cm. from the surface. The depression was then refilled and lightly tamped down. After a rain and subsequent drying out period, crust strength was measured by the amount of pressure it took to remove the button. Figure 1 shows the portable apparatus that was used. The button was attached to a string which was in turn attached to a spring scale. The pressure was applied by a constant addition of water to the bucket (~ 0.8 ℓ/min. The scale was read as the button broke through the soil. In 1980 a laboratory spring scale was used which had a constant reading scale. In 1981 a scale was used which had a maximum reading guage. This maximum reading guage considerably reduced the variability in readings. A soil sample was taken from each split plot to determine moisutre content at the time crust measurements were taken.

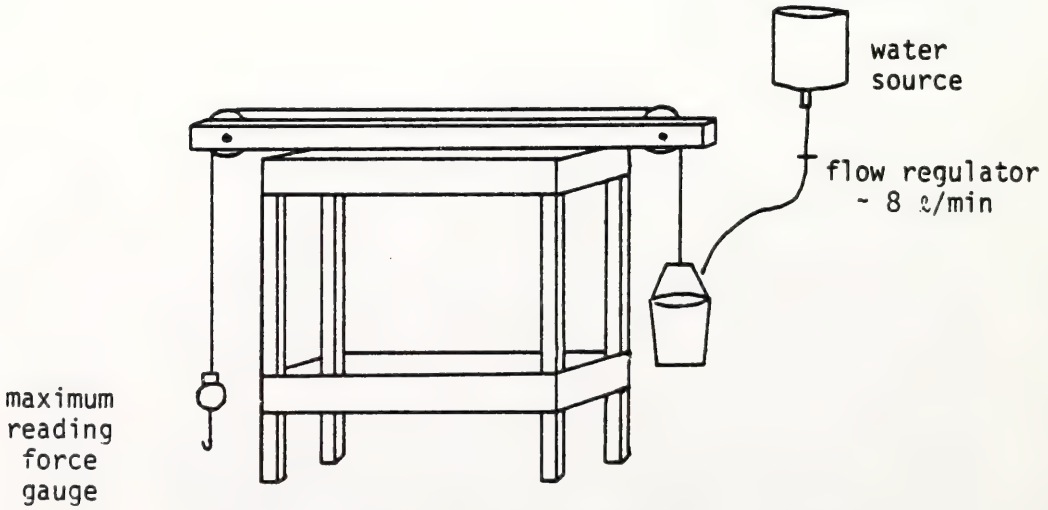

FIGURE 1. *Apparatus used to measure crust strength.*

Two 5.3 m sections from two different rows in each half plot were hand harvested to determine corn yield. Soybean yields were obtained from machine harvest.

Results

Table 1 contains the measurements of bulk density. There are no statistically significant differences (at 0.10 level) in the bulk density data.

There were no statistically significant differences in the wet aggregate stability of the three soil conditions. The well structured, Chalmers soil in Condition I had a slightly higher average mean size of water stable aggregation than either of the other two soils. The Raub soil which has the poorest structure also has the lowest average mean of water stable aggregation.

Crust Strength

There are differences in crust strength between the three soil conditions (Table 3). In 1980, even with a great deal of variability in the data because of the scale used,

TABLE 1. *The effects of different tillage treatments on three soils as measured by Bulk Density g/cm ÷ (coated clod method).*[1]

Tillage		Soil		
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression	Chalmers Intermediate	Raub
		g/cm³	g/cm³	g/cm³
1	0	1.52	1.63	1.62
1	1	1.63	1.59	1.62
1	2	1.58	1.51	1.55
0	0	1.59	1.50	1.56
0	1	1.70	1.62	1.58
0	2	1.75	1.70	1.61

1 Samples taken from the surface.
Not significant at 0.05 level.

CV = main plot/soils 4.8%
CV = sub plot 5.3%

TABLE 2. *The effect of tillage treatment on three soils as measured by Mean Weight Diameter of water stable aggregates.*

Tillage		Soil		
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression	Chalmers Intermediate	Raub
		mm	mm	mm
1	0	0.90	0.69	0.99
1	1	0.70	0.56	0.55
1	2	0.91	0.84	0.45
0	0	0.59	0.49	0.60
0	1	1.15	0.76	0.82
0	2	0.79	0.94	0.49

Not significant at 0.05 level.
CV = main plot 27%
CV = subplot 17%

TABLE 3. *Crust strength measurements (g/cm^2) for each soil condition and secondary tillage treatment.*

Tillage		1980 Soil						1981 Soil					
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression		Chalmers Intermediate		Raub		Chalmers Depression		Chalmers Intermediate		Raub	
		g/cm^2	$\%H_2O$	g/cm^2	$\%H_2O$	g/cm^2	$\%H_2O$	g/cm^2	$\%H_2O$	g/cm^2	$\%H_2O$	g/cm^2	$\%H_2O$
1	0	810	15	1085	14	1200	11	233	7	629	7	874	6
1	1	724	14	822	11	1272	16	186	7	520	7	774	6
1	2	960	14	1004	16	1284	14	193	7	277	6	842	6
	Average	831		970		1252		204		478		830	
0	0	736	12	930	14	1203	15	505	6	568	6	709	6
0	1	800	11	1172	10	1346	8	333	7	526	4	785	6
0	2	770	12	709	21	1109	14	208	8	303	5	642	6
	Average	769		973		1219		349		466		712	
average across soil		a		a		a		b		c		d	

Columns with different letter are significantly different at 0.01 level.

	1980	1981
CV main plot =	21.8%	39.9%
subplot =	19.7%	33.0%

soil condition had a statistically significant influence (0.10 level) on crust strength when all treatments are averaged. In 1981, the technique used to measure crust strength was refined and the degree of variability reduced. The effect of soil condition on crust strength when averaged for all treatments was highly significant (0.01 level). The overall differences between the data collected in 1980 and 1981 was due to the technique being refined in 1981 and crust strength measurements being taken in a drier period in 1981. The moisture content of the soil averaged 14% in 1980 and 6% in 1981. Although crust strength increases as the soil becomes drier, it does so only until the point of cracking. Cracking decreases crust strength as the emerging button takes advantage of the natural cracking in the soil. Whole crusted areas are lifted instead of a break in the crust immediately surrounding the button. Seedlings are capable of this same action (Arndt, 1965a & b).

Emergence

The data for 1980 shows no statistically significant difference in emergence of corn seedlings either due to soil or tillage treatment (Table 4). In 1981 there is a

TABLE 4. *The average total number of plants emerged per 5.3 meters.*

TILLAGE		1980 Crop: Corn			1981 Crop: Soybeans		
		Soil			Soil		
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression	Chalmers Intermediate	Raub	Chalmers Depression	Chalmers Intermediate	Raub
		# emerged	# emerged	# emerged	# emerged	# emerged	# emerged
1	0	22	20	18	126	128	125
1	1	20	20	21	125	130	125
1	2	22	19	19	127	121	130
	Average	21	20	20	126	127	127
0	0	20	20	18	119	117	124
0	1	20	19	19	116	129	124
0	2	22	19	22	130	121	122
	Average	21	19	20	122	122	124

Not significant at 0.05 level

CV main plot = 5.2% 1980
CV subplot = 4.9% 1981

CV main plot = 5.0% 1980
CV subplot = 9.7% 1981

statistically significant effect (0.10 level) on emergence of soybean seedlings produced by the power harrow for each soil conditions averaged over all treatments. This may relate to the sifting of the finer particles which decreased the effective crust strength and allowed greater emergence.

Yield

Any differences in corn and soybean yields either among soils or due to tillage treatment were slight and not statistically significant (Table 5 and 6). The tendency for less secondary tillage to result in lower soybean yields appeared to be related to weed control, but the difference was not statistically significant.

TABLE 5. *1980 corn yield (Tonnes/ha) as related to soil and secondary tillage treatment.*

Tillage		Soil		
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression	Chalmers Intermediate	Raub
		T/ha	T/ha	T/ha
1	0	10.50	10.29	10.56
1	1	9.08	10.83	11.24
1	2	9.89	10.83	10.97
0	0	10.97	9.49	10.45
0	1	9.96	10.63	11.10
0	2	10.16	10.76	10.63

Not significant at 0.05 level.

Summary and Conclusions

During the two years of the study the secondary tillage treatments used had no statistically significant effect on bulk density or wet aggregate stability of the soils. Little change had been expected because of the brevity of the treatments. In 1981 the Chalmers in the depression had an average crust strength of 276 g/cm^2; the intermediate Chalmers, 472 g/cm^2; the Raub, 771 g/cm^2. The Chalmers soils were well structured, and crust strength may not be as easily affected by management as the Raub. Emergence of soybeans was increased by the power harrow.

It may be possible to draw in references regarding some common management practices. On these particular soils, no increase in yield was obtained from increased secondary tillage. Modern planters and cultural practices may not require as many secondary tillage operations as was previously thought necessary to obtain an adequate seed bed and plant population.

This study demonstrated the field capability of the crust strength measurement that was used. There is virtually no disturbance of the soil involved, and it can be successfully done on plots planted to field crops using standard practices.

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TABLE 6. *1981 Soybean yields (Tonnes/ha) as related to soil and secondary tillage treatment.*

Tillage		Soil		
Trips with Power Harrow	Trips with Disk Harrow	Chalmers Depression	Chalmers Intermediate	Raub
		T/ha	T/ha	T/ha
1	0	2.7	2.3	2.5
1	1	3.2	3.3	3.1
1	2	2.9	3.1	2.9
0	0	2.6	2.3	2.5
0	1	3.1	3.2	3.4
0	2	2.8	3.0	3.2

Not significant at 0.05 level.

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Land Use Changes and an Estimate of Prime Farmland Loss to Development in Hamilton County, Indiana 1940-1980

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Introduction

The 1980 U.S. Census has shown that for the first time in the history of this country, rural population is growing as fast as urban population (7). The effect of this movement on rural land use changes and on prime farmland conversion is the subject of this study.

The National Agricultural Land Study (NALS) has indicated that of the new houses build in the 1970's, over 40 percent were constructed on rural lands (3). Any population increase in rural areas has both direct and indirect effects on agriculture. The most obvious direct effect is the conversion of farmland to other uses. The most common indirect effect has been termed the "impermanence syndrome" (1). As farmers' beliefs in the longevity of their farming operations decrease, their long-term capital investment in those operations also decrease. Thus, the "impermanence syndrome" can be observed in such things as lowered production, run down buildings and equipment, and a decrease in use of some conservation practices.

According to NALS between 1967 and 1975 in the North Central Region about 5.2 million acres of agricultural lands were converted to other uses. This region includes the lake states of Michigan, Wisconsin and Minnesota; the corn belt states of Ohio, Indiana, Illinois, Iowa and Missouri; and the northern plains states of Kansas, Nebraska, South Dakota, and North Dakota. Indiana has seen the conversion of about 740,000 acres of agricultural lands to urban built-up, transportation, and water during a similar period from 1967-1977 (5). In 1979 the Land Use Subcommittee of the Legislative Interim Study Committee of the Indiana General Assembly found that about 88,000 acres of Indiana land were being converted to non-agricultural uses every year (6). A micro-scale example of this process can be found in Hamilton County, Indiana, north of Indianapolis. Between 1940 and 1980 the population of the county rose from 24,614 to 82,027. Just over 25% of this growth occurred between 1960 and 1970, while about 48% occurred between 1970 and 1980 (2). To understand how this growth has affected land use change, especially conversion of prime farmland, the concept of Relative Development Values (RDV) was employed as a study tool.

Relative Development Values

Using plat books available for the years 1940, 1960, 1970 and 1980, a methodology has been developed to (1) observe land change by section in the county and (2) indicate a Relative Development Value (RDV) for the townships in each of the years cited. Plat book information for 1950 was not available.

Subdivision and tract lands present in any given year are indicated in plat books. Subdivisions are aeas of land divided into parcels for residential development, while tracts are areas designated for future subdivisions. Approximation of these as a development percentage per section was done. Five development ranges were arbitrarily selected: 0%, 0-25%, 25-50%, 50-75%, and 75-100%. The 0% development range indicated that

no development had taken place in the section beyond the farmstead level. A development level of 0-25% indicated that some development in the form of a subdivision or tracts had taken place, but that it covered less than 25% of the land surface of the section.

With this simple method maps were prepared delineating the percentage range of development of each section in Hamilton County for the years 1940, 1960, 1970, and 1980 (Figure 1). Changes in any given section can be observed over time on the maps. Note that some sections actually appeared as less developed in 1970 than in 1980 in Washington Township. This was because some tracts designated for development in 1960 were never developed and had reverted to farmland by 1970.

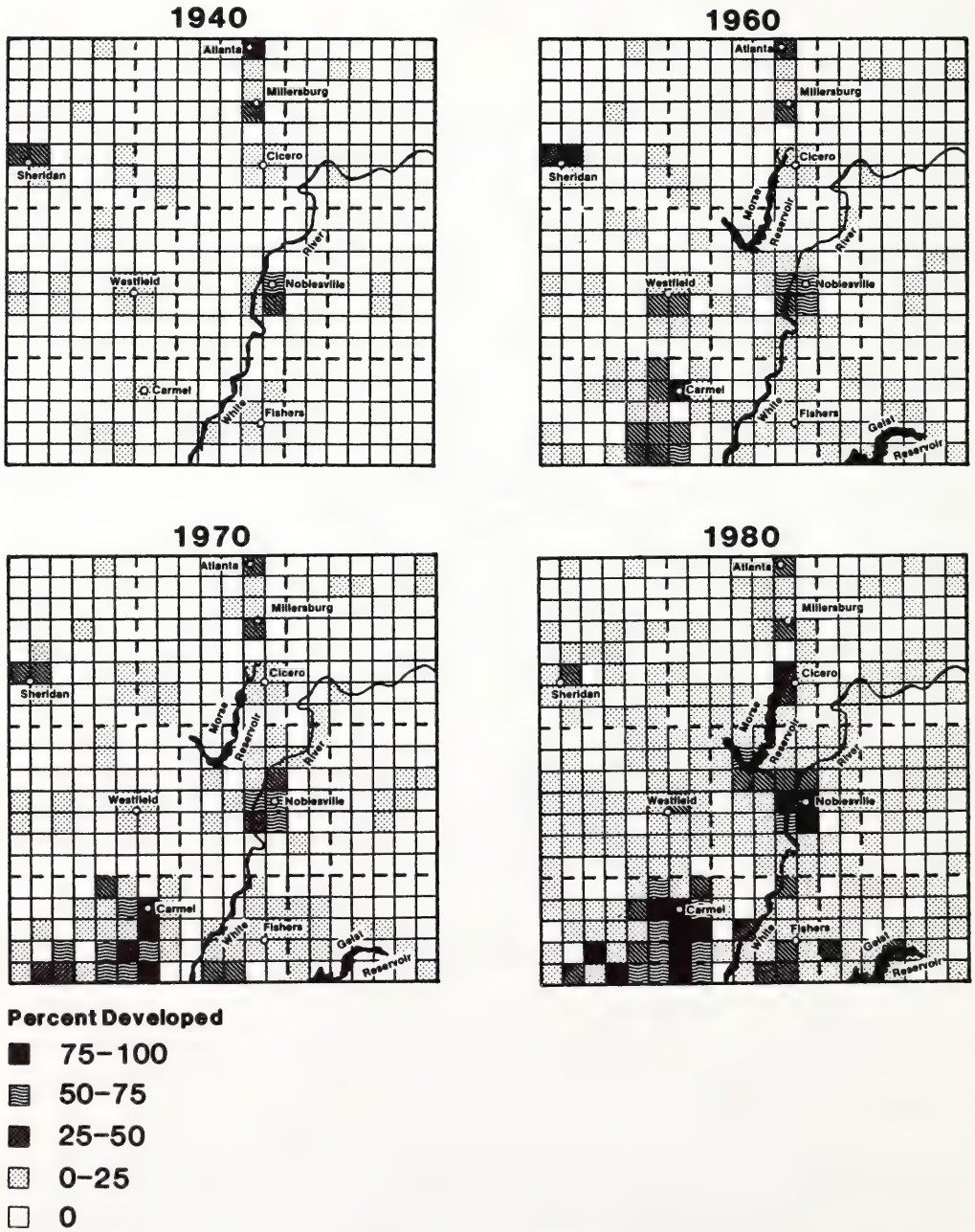

FIGURE 1. *Land Development by Section in Hamilton County, Indiana (1940-1980)*

From this evaluation a Relative Development Value (RDV) was determined for each township for each year. Methodology for this required first a compilation of the number of sections in each development range for each year (Table 1). Then a weighted value for each component was determined by multiplying the number of sections in each range (Table 1) by the mid-point percentage value of the range. For example the mean value for the range 0-25 is 12.5. In Adams Township in 1940 there were five sections in the 0-25 range. The weighted development values for each range

TABLE 1. *Number of Sections Per Development Ranges (%) for Hamilton County, Indiana (1940-1980)*

TOWNSHIP	SEC PER TWP	1940 DEVELOPMENT RANGE				
		0%	0-25%	25-50%	50-75%	75-100%
		NUMBER OF SECTIONS				
Adams	48	41	5	2	0	0
Clay	50	45	5	0	0	0
Delaware	15	11	4	0	0	0
Fall Creek	35	35	0	0	0	0
Jackson	56	46	8	2	0	0
Noblesville	49	45	2	1	1	0
Washington	36	46	10	0	0	0
Wayne	35	33	2	0	0	0
White River	56	52	4	0	0	0
TOTALS	400	354	40	5	1	0

TOWNSHIP	1960 DEVELOPMENT RANGE				
	0%	0-25%	25-50%	50-75%	75-100%
	NUMBER OF SECTIONS				
Adams	41	5	2	0	0
Clay	25	16	7	1	1
Delaware	6	9	0	0	0
Fall Creek	24	11	0	0	0
Jackson	45	9	2	0	0
Noblesville	32	13	1	3	0
Washington	40	14	2	0	0
Wayne	32	3	0	0	0
White River	52	4	0	0	0
TOTALS	297	84	14	4	1

TOWNSHIP	1970 DEVELOPMENT RANGE				
	0%	0-25%	25-50%	50-75%	75-100%
	NUMBER OF SECTIONS				
Adams	40	6	2	0	0
Clay	22	15	3	6	4
Delaware	4	9	2	0	0
Fall Creek	23	12	0	0	0
Jackson	43	11	2	0	0
Noblesville	34	10	2	3	0
Washington	46	10	0	0	0
Wayne	30	5	0	0	0
White River	50	6	0	0	0
TOTALS	292	84	11	9	4

TABLE 1.—Continued

TOWNSHIP	1980 DEVELOPMENT RANGE 0%	0-25%	25-50%	50-75%	75-100%
	NUMBER OF SECTIONS				
Adams	28	19	1	0	0
Clay	9	20	7	7	7
Delaware	0	11	4	0	0
Fall Creek	8	25	2	0	0
Jackson	31	21	4	0	0
Noblesville	6	34	4	2	3
Washington	15	40	1	0	0
Wayne	17	18	0	0	0
White River	39	17	0	0	0
TOTALS	153	205	23	9	10

gave the weighted development values for each township and the county in specified years.

A Relative Development Value for each township was calculated by dividing the total of the weighted values by the number of sections in each township (Table 2). Adams Township in 1940 had a weighted development value of 137.5 and 48 sections. Thus its rounded RDV was 3.

The highest possible RDV in each township was 88. If all sections in the township were fully developed, the mid-point of the highest weighted development level (87.5) rounded off to 88 would be the RDV for each township since the number of sections cancel each other in the RDV procedure. In a like manner the highest possible RDV for the whole county would be 787.5 rounded to 788. By dividing the RDV for each section of the county in each year by the highest theoretical value that could be obtained, a relative percentage of development for each township or the county in each year was obtained (Table 3). This figure indicated the relative amount by percentage of the total land development that had occurred by a given date in the townships and the county. For example, better than one-third of the land surface in Clay Township had been developed into subdivisions and tracts by 1980, as had just over one-fifth of the land in Noblesville and Delaware Townships.

Using Table 3 as a base, a change in the relative percentage of land development showed how the development of subdivisions and tracts has progressed in each township over time (Table 4).

TABLE 2 *Relative Development Values (RDV) for Hamilton County, Indiana (1940-1980)*

TOWNSHIP	1940	1960	1970	1980
Adams	3	3	3	6
Clay	1	12	21	31
Delaware	3	8	13	19
Fall Creek	0	4	4	11
Jackson	3	3	4	7
Noblesville	3	8	8	20
Washington	2	4	2	10
Wayne	1	1	2	6
White River	1	1	1	4
TOTALS	17	44	58	114

TABLE 3 *Relative Percentage of Land Development By Township in Hamilton County, Indiana (1940-1980)*

TOWNSHIP	1940 %	1960 %	1970 %	1980 %
Adams	3	3	3	7
Clay	1	14	24	35
Delaware	3	9	15	22
Fall Creek	0	5	5	13
Jackson	3	3	5	8
Noblesville	3	9	9	23
Washington	2	5	2	11
Wayne	1	1	3	7
White River	1	6	7	14
TOTAL	2	6	7	14

Prime Farmland

In Indiana the Soil Conservation Service (SCS) has used a set of predetermined criteria to classify those soils that are considered prime farmland (9). Using the list of soils found in the county, each can be defined as prime or non-prime farmland. Finally, the amount of prime farmland in the county can be determined by addition of the acreage of prime farmland soil as listed in the *Soil Survey of Hamilton County* (4).

Of the thirty soils listed which compose Hamilton County's land surface, eighteen meet the criteria for prime farmland soil. These accounted for 88 percent or 226,087 acres of the total of 256,640 acres in the county (Table 5).

Preliminary Results

As indicated below (Table 4) between 1940 and 1980 about 12% of the land surface of Hamilton County was occupied by subdivisions and tracts. Also as indicated above, prime farmland accounted for about 88% of the land surface of the county. The assumption was made that prime farmland was spread rather evenly throughout the county. All of Hamilton County is in one physiographic region—the Tipton Till Plain. Other than the valley of the White River, about one section side, and other smaller drainageways, the landscape and soils are similar over the whole country (8). With

TABLE 4 *Change in Relative Percentage of Land Development in Hamilton County, Indiana (1940-1980)*

YEARS TOWNSHIP	1940-1960 %	1960-1970 %	1970-1980 %
Adams	0	0	4
Clay	13	10	11
Delaware	6	6	7
Fall Creek	5	0	8
Jackson	0	2	3
Noblesville	6	0	14
Washington	3	-3	9
Wayne	0	1	5
White River	0	0	4
County Average Totals	4	1	7

TABLE 5 *Prime Farmland Soils of Hamilton County*

Map Symbol	Soil Name	Acres of Land	Percent Farmland	Prime Farmlands
Br	Brookston silty clay loam	62,510	24.4	x
CrA	Crosby silt loam, 0-3% slopes	93,746	36.5	x
FnA	Fox loam, 0-2% slopes	1,402	0.5	x
FnB2	Fox loam, 2-6% slopes, eroded	1,465	0.6	x
FxC3	Fox clay loam, 8-18% slopes severely eroded	1,099	0.4	x
Ge	Genesee silt loam	3,295	1.3	
HeF	Hennepin loam, 18-50% slopes	1,960	0.8	
Ho	Houghton muck	321	0.1	x
MmA	Miami silt loam, 0-2% slopes	7,718	3.0	x
MmB2	Miami silt loam, 2-6% slopes eroded	29,379	11.4	x
MmC2	Miami silt loam, 6-12% slopes eroded	3,923	1.5	
MmD2	Miami silt loam, 12-18% slopes eroded	1,311	0.5	
MoC3	Miami clay loam, 6-12% slopes severely eroded	3,496	1.4	
MoD3	Miami clay loam, 12-18% slopes severely eroded	946	0.4	
MxA	Milton Variant silt loam, 0-2% slopes	701	0.3	x
NnA	Nineveh loam, 0-2% slopes	228	0.1	x
OcA	Ockley silt loam, 0-6% slopes	8,278	3.2	x
OcB2	Ockely silt loam, 2-6% slopes eroded	1,225	0.5	x
Or	Orthents	1,044	0.4	
Pa	Palms muck	217	0.1	x
Pn	Patton silty clay loam	11,158	4.3	x
Ps	Patton silty clay loam, limestone substratum	501	0.2	x
Pt	Pits	1,017	0.4	
Ra	Randolph Variant silt loam	336	0.1	x
Ro	Ross loam	656	0.3	
Sh	Shoals silt loam	6,775	2.6	
St	Sleeth loam	931	0.4	x
Sx	Sloan silty clay loam, sandy substratum	1,273	0.5	
We	Westland silty clay loam	4,886	1.9	x
Wh	Whitaker loam	1,007	0.4	x
	Water areas	3,758	1.5	
	TOTAL	256,640	100.0	226,087 ACRES

this assumption, if 12 percent of the county's land surface was developed, then over 10 percent of the land surface was developed on prime farmlands. Thus, about 27,000 acres of prime farmlands in the county were occupied by subdivisions and tracts between 1940 and 1980. This represents about 42 sections out of the 400 in the county or about the equivalent area of Adams Township.

It should be noted that this development was not evenly spread. While White River and Adams Townships have seen only an estimated 4 percent of their land surface developed in this period, Clay Township has seen better than one-third of its area developed. Also, about 20 percent of Delaware and Noblesville Townships has been developed. Thus, it can be surmised that more prime land was lost in Clay, Noblesville, and Delaware townships than in the others.

Finally, of this 27,000 acres of prime farmland, about 15,800 acres or about 6 percent of the county's total prime farmland were lost in the period between 1970 and 1980. It is difficult to tell if a trend has as yet been established because the prime farmland converted to subdivisions and tracts between 1960-1970 was less than one percent of the total.

Obviously there is at last one major flaw in this determination of prime farmland loss. In describing actual land loss we have neglected the indirect effect. Not as yet accounted for are the "impermanence syndrome" lands described earlier. Expecta-

tions are that parcels in the limbo of impermanence would add significantly to the county's potential loss of prime farmland to other uses. However, no means of measuring this loss has yet been established. One indication, however, may be shown by an estimation of the number of these parcels per section found in each township in specific years (Table 6). A parcel implies a particular piece of real estate and its improvements.

TABLE 6 *Average Number of Parcels 30 Acres or Less in Size Per Section Per Township in Hamilton County, Indiana (1940-1980)*

	1940	1960	1970	1980
Adams	3.1	2.3	2.8	3.5
Clay	2.2	3.1	6.9	5.7
Delaware	2.4	4.3	5.2	4.9
Fall Creek	2.3	2.5	4.3	5.8
Jackson	3.0	2.2	3.5	3.6
Noblesville	2.9	1.8	4.8	4.1
Washington	3.2	3.2	5.2	6.4
Wayne	2.2	1.6	3.5	4.0
White River	1.3	1.2	1.5	2.0
COUNTY	2.5	2.5	4.2	4.4

Several observations can be made from Table 6. First, it should be noted that for the county as a whole, there was no overall change in the average number of "impermanence syndrome" parcels between 1940 and 1960 although individual townships changed. Second, most parcel development in the country occurred between 1960 and 1970, where on the average 1.7 parcels, 30 acres or less in size, were subdivided in each section. Third, Washington Township (6.4), Fall Creek Township (5.8), and Clay Township (5.7) appeared in 1980 to have the most "impermanence syndrome" parcels per section. Fourth, if an average of 1.9 parcels, 30 acres or less in size, have been divided off in each section of the county (using 15 acres as an average size), a total of 11,400 acres of farmland have been influenced by the characteristics of impermanence since 1940. If it was also assumed that 88 percent of this was prime farmland, then about 10,000 additional acres of prime farmland have been used for this type of development from 1940 to 1980. Therefore, about 37,000 acres of prime farmland have been consumed by some form of development from 1940 to 1980 in Hamilton County. This is the equivalent of just over 14 percent of the total county and just over 16 percent of the county's prime farmland.

Summary

Hamilton County, Indiana between 1940 and 1960 saw relatively little in the way of development changes. However, the 1960-1970 period appears to have been a time of movement to rural non-farm acreages. Clay and Noblesville Townships were the most affected and Adams and White River the least. The 1970-1980 period was one of rapid expansion of subdivisions and tracts. Again, Clay and Noblesville Townships led the way. Much of this expansion occurred around several towns including Noblesville and Carmel.

About 37,000 acres of prime farmland have been diverted to other than farmland uses between 1940 and 1980. This is equivalent to just over 14 percent of the county and is larger than any one of the nine townships in the county. About 27,000 acres

of prime farmland (12%) went into subdivisions and tracts and about 10,000 acres of prime farmland (4%) were designated "impermanence syndrome" lands.

By 1980 over 62,000 total acres in the county were used for other than agricultural purposes or reduced in production. This is almost one-fourth of the county. Based on the analysis of the data, almost 55,000 acres of this was prime farmland. Better than 66 percent of this prime farmland conversion occurred in the 1940-1960 period.

Finally, the "impermanence syndrome" lands accounted for about 42 percent of this 62,000 acres or over 26,000 acres by 1980. This figure is about 12 percent of the country's total prime farmland.

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ZOOLOGY

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ABSTRACTS

Deodorizing (Descenting) in the Male Common American Goat (*Capra hircus*). JACK L. ALBRIGHT, Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47907.——Since ancient times the musky odor of the male (buck) goat has been proverbial as well as a nuisance and burden to goat keepers. The buck's odor seems to be stronger about the head. Earlier anatomical studies (Sar, M. and M. L. Calhoun. Am. J. Vet. Res., 27: 444-56. 1966) revealed two small patches of specialized glossy skin located adjacent to the horns, along the inner and rear margins. Called musk patches, these are large, branching alveolar sebaceous glands. Large branched alveolar glands are also found at junctions of the hoof with the skin, base of the ear, base of the horn and in the perianal region. After surgical removal of the large, branched, alveolar, sebaceous glands at the base of the horn and in the perianal region, the characteristic male goat odor returned in one male goat. The characteristic male goat odor did not appear in one male goat after the musk patches in the head region were burned away with an electric calf dehorner at disbudding. These two males and two other males serving as controls were all within the 4-6 months of age group. It is speculated that a difference in odor exists between breeds of goats. The Saanen male seems to have less of the characteristic male odor than the darker skinned breeds such as the French Alpine. It has been suggested (Hull, B. L. and M. C. Smith, Ext. Goat Hb., II (6): 1-12). 1983) that bucks with a high odor level are more stimulating to female goats. However, goat odor is very offensive to most people and makes the production of clean, pleasant tasting milk difficult. Therefore, it is advisable to descent goats during dehorning.

Osmotic Studies on the Holostean *Lepiosteus platostomus*. D. W. DUFF, Department of Biology, Indiana University at South Bend, South Bend, Indiana 46634.——Shortnose gar, *Lepisoteus platostomus*, were tested for salinity tolerance. These animals can survive in a hyperosmotic environment but are not able to maintain the osmotic concentration of their plasma at freshwater levels. Upon transfer from freshwater to saline solutions (16%, 30%, and 44% sea water) sodium efflux increased from 0.43 μM Na/gr/hr in freshwater to a high of only 1.16 μM Na/gr/hr in 30% and 44% sea water. This increase in sodium efflux is not sufficient to rid the animal of the impinging salt load which it absorbs from its external environment. Total body sodium levels remained essentially similar in all salinities. Thus, it would appear *L. platostomus* is not able to expand its sodium space as seen in several teleosts.

Developmental Temperature and Emydine Turtle Systematics. MICHAEL A. EWERT and CRAIG E. NELSON, Indiana University, Bloomington, Indiana 47405.——The normally viable incubation temperatures of 25° and 30° C result in hatchling turtles with significant morphological differences including differences in head size and in skin and shell

pigmentation. In some cases, the variation is sufficient to switch some "key characters" from those of one taxon to those of another. Cooler temperatures make the color patterns of some taxa lighter or more dispersed and make those of others darker or more localized. Sex of the study species is also known to be determined by incubation temperature: 25° C results in males, 30° C in females. Because both sex and morphometrics are affected by temperature, hatchlings emerge with a rudimentary secondary sexual dimorphism that may only casually be related to gonadal sex. A design of analyzing this system further also will be presented.

A Tooth-marked, Late Pleistocene-early Holocene Deer Antler (cf. *Cervalces scotti*) from Northwestern Allen County, Indiana. JAMES O. FARLOW, TIMOTHY J. NCNITT and DIANE E. BEYNON, Indiana University-Purdue University at Fort Wayne, 46805.——A fragmentary left antler of an extinct deer was found during dredging of a bog southeast of Churubusco, Indiana. Its precise stratigraphic context is uncertain. The burr, beam, and proximal portions of the posterior ascending tine and palmation of the antler are preserved. Maximum burr diameter is about 7 cm. Beam length from burr to posterior ascending tine is 27-28 cm; midshaft beam diameter is 4 ½- 5 cm. The antler is provisionally assigned to *Cervalces scotti*. Two prominent sets of tooth marks scar the specimen. The first consists of at least five shallow, transverse grooves on the dorsal mid-portion of the beam. Each groove is about 1 cm long and ½ cm wide, and separated by ½-1½ cm from neighboring tooth marks. The second set is located near the proximal end of the dorsal surface of the posterior ascending tine. These transverse marks are comparable in size to those on the beam, but immediately abut each other with no intervening gaps.

The Application of Chromosome Analysis for Breeding Management of Squirrel Monkeys. THOMAS A. FOGLE, CAROL E. CAHALAN, and MARY BETH FERSTEL, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Differences in the number of acrocentric chromosomes characterize the three known geographic races of squirrel monkeys, *Saimiri sciureus*. Eight animals from the Potawatomi Zoo in South Bend, Indiana were analyzed cytogenetically from cultured lymphocytes. The colony includes two Peruvian females, one Colombian female, four Peruvian males, and one Peruvian-Colombian hybrid male. The hybrid, which contains a chromosome pair that differs by a pericentric inversion, has chromosomal segments distal to the inversion that are 1.0% and 0% of the total haploid autosomal length. When compared to similar sized segments from data derived from humans, it is likely that a single crossover within the inverted region would provide a severe congenital defect.

Detection and Preference of Conspecific Odor Cues among Female Hamster Conspecifics. BONNIE GRAY, ROBERT B. FISCHER and GARY F. MEUNIER, Department of Psychological Science, Ball State University, Muncie, Indiana 47306.——Female hamsters were tested in a four-choice olfactorium to determine if they could differentiate and demonstrate a preference for salivary cues as a function of the subjects dominance status and estrous state. Clear differences in responding were found for estrous as opposed to diestrous females. No differential responding was evident when subject status was examined. The estrous females detected the stimuli and exhibited a preference for male as opposed to female sample odors on the basis of the entry/approach scores. The subjects were found to exhibit sniffing preferences for male odors and possibly avoidance of female odors relative to the saline control. Unlike urinary odor cues, estrous females apparently are unable to distinguish between males on the basis of

their dominance status. These results expand the growing body of data concerning the salience of salivary odor cues in modifying the behavior of mammals.

Histological Investigation of Tannic Acid Detoxication of Hepatic and Renal Tissue of *Tamascrius hudsonicus*. M. J. HART AND E.D. MOULD, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Red squirrels (*Tamascrius hudsonicus*) naturally consume forages of relatively high phenolic content, including tannins. Tannins are potentially toxic and can inhibit metabolic processes by bonding in hepatic and renal tissue as has been observed in laboratory animals. We sought to evaluate the potentialities of these processes in red squirrels. Captive red squirrels were fed tannic acid laced diets of up to 5.00% of dry matter. Hepatic and renal tissue sections were obtained and stained with 1) Hematoxylin and Eosin and 2) Periodic Acid-Schiff and Fast Green FCF counterstain. Normal hepatic and renal architecture was observed Extensive fatty metamorphosis and hepatocytes were noted in two experimental tannin diet subjects. Hepatic and renal tissues evidenced no notable changes in glycogen content between control and tannin consuming subjects.

Saliva as a Chemosignal in Intra-sexual Communication. CHANDRASHEKHAR KAPADNIS, ROBERT E. FRIEDLE, ROBERT B. FISCHER AND GARY F. MEUNIER, Department of Psychological Science, Ball State University, Muncie, Indiana 47306.——When Syrian hamster females encounter one another in a neutral arena, they engage in nasal-oral investigation which is followed by agonism which leads to the establishment of dominance relationships. This study investigates the possibility that saliva may convey a message concerning the sex and dominance status of one animal to the partner during the buccal investigation which precedes fighting.

Clean air was directed over saline and salivary samples obtained from pairs of dominant and submissive females and males. The female subjects were tested during estrous and diestrous in an open-field olfactorium. The estrous females were found to engage in a greater number of investigatory acts and to differentiate among the stimuli on the basis of sniffing frequency. These females directed the greatest amount of sniffing to the odors obtained from the dominant females. Diestrous females were either unable to differentiate among the stimuli or were not motivated to respond.

The data demonstrate that saliva is an effective social stimulus for estrous females. The apparent attraction to the odors of the dominant female is probably best explained as an effective long term fitness enhancing strategy. A desert dwelling, territorial female would do well to attend to conspecifics whose presence might threaten a reproductive females limited resources.

Specificity of the α-tocopherol (Vitamin E) Effect on the Lifespan of Bdelloid Rotifers. JAMES R. LITTON, JR., Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——Clones of the bdelloid rotifers *Pleuretra, Rotaria, Habrotrocha*, and *Philodina* showed an extension of lifespan when *d*-α-tocopherol was added to their aqueous culture medium at concentrations of 10^{-4} to 10^{-6}M. The specificity of this response was tested by adding a variety of natural and synthetic tocopherol and antioxidant compounds to the aqueous culture media of these rotifers. Compounds tested, at concentrations of 10^{-3} to 10^{-8}M, include: β-tocopherol, λ-tocopherol, δ-tocopherol, α-tocotrienol, *l*-α-tocopherol, 2,5,7,8-tetramethyl-2-(4′,8′-dimethylnonyl)-6-hydroxy-chromane, *dl*-α-tocopheramine, 5,5′ βi-α-tocopherol, α-tocopherol quinone, tocopherolactone, ethoxyquin, menadione, sodium selenate, and *dl*-methionine. Only β- and λ-tocopherol resulted in a significantly larger lifespan in all

genera. While these two tocopherol compunds increased in lifespan slightly they were significantly less effective than *d*-α-tocopherol and showed only 20% of its activity, even a higher culture concentration. In addition the β- and λ-tocopherols did not show the increased fecundity or higher percentage of survival at a later age noted for *d*-α-tocopherol.

The Effect of Single and Divided Dose Administration on the Efficacy of Oxfendazole against *Trichinella spiralis*. R. O. McCracken, D. M. Nierste, J. Moss and A. Garcia. Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——The effects of two different treatment regimens on the efficacy of oxfendazole against *Trichinella spiralis* in experimentally infected mice were studied. In the first set of experiments, mice infected with adult *T. spiralis* were used to compare the anthelmintic efficacy of oxfendazole given as a single oral dose or administered as a series of divided daily oral doses during the intestinal phase of infection. Given as a single oral dose of 100 mg/kg 72 hr after exposure to infection, oxfendazole reduced the worm burden by 65% as determined at necropsy on day 7 postinoculation. In contrast, twice-daily oral doses of oxfendazole at 12.5 mg/kg for 4 consecutive days during the intestinal phase (i.e., a total dose of 100 mg/kg body weight) was more effective against the drug-resistant adults; this treatment regimen reduced the worm burden by 85%. In the second set of experiments, oral administration of oxfendazole at 12.5 mg/kg twice-daily for 4 consecutive days during the invasive and encystment phases of trichinellosis significantly reduced (92 and 99%, respectively) the number of larvae subsequently recovered from the host musculature on day 56 postinoculation. The demonstrated role of the period of exposure to the anthelmintic as a determinant of its efficacy and spectrum of action has important therapeutic implications for extending the range of life cycle stages of *Trichinella* against which oxfendazole is effective, and for achieving efficacy with low dosage rates.

The Mating Behavior of the Tree Frog *Hyla versicolor*. Molly Morris, Department of Biology, Indiana University, Bloomington, Indiana, 47405.——The mating behavior of *Hyla versicolor* is described and compared to the behavior of other anurans. From field observations it is hypothesized that females are selecting mates based on a characteristic of the male's call and that females are stimulated to ovulate by the chorus. Calling males were not site specific but remained spaced and intolerant of other males calling in close proximity. Factors influencing a species breeding behavior are discussed.

Male Mating Strategies in Three Hylid Frogs. Stephen A. Perrill, Department of Zoology, Butler University, Indianapolis, Indiana 46208.——Populations of *Hyla cinerea* in Georgia, *Hyla regilla* in California and *Hyla versicolor* in Indiana were studied with regard to male mating strategies. To facilitate individual identification in the field, the dorsal surfaces of the frogs were freeze-branded. Some males of all three species call from stationary call sites throughout a given night, as well as on consecutive nights. Also, all three species have some calling males that move from one call site to another, often being chased away by the territorial males that call from fixed locations. *Hyla cinerea* and *Hyla regilla* have non-calling, satellite males that maintain a low posture close to calling males and attempt to intercept females on their way to calling males. Individual differences in mating success are based on a number of variables including mating strategy. Males employing each of the three strategies discussed here were successful in obtaining mates.

Comments on the Occurrence of Blanding's Turtle, *Emydoidea blandingi*, in LaPorte and Saint Joseph Counties, Indiana. David M. Sever, Department of Biology, Saint

Mary's College, Notre Dame, Indiana 46556.——Blanding's turtle is a Great Lakes endemic which has a spotty distribution, especially in the eastern end of its range. Minton (1972. *Amphibians and Reptiles of Indiana*) did not report any records from LaPorte and Saint Joseph Counties and stated that the species is apparently faced with extinction in Indiana. On 22 and 23 August, 1983, I collected adult male individuals in LaPorte and Saint Joseph Counties respectively. The LaPorte County specimen (carapace length 23.0 cm) was found in Breckinridge Ditch, Kingsbury State Fish and Wildlife Area, by seining. This individual is the largest Blanding's turtle ever reported from Indiana. The Saint Joseph County specimen (carapace length 19.5 cm) was found AOR on a road which borders a small swamp at the western edge of the city of South Bend. Both specimens have been deposited in the Carnegie Museum, Pittsburgh.

Quantitative Habitat Responses of *Peromyscus leucopus* and *Tamias striatus*: Results and Implications. DAVID P. VERNON, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.——Simple rapid techniques, using inexpensive instruments, were devised to collect quantitative data single-handed on habitat variables pertinent to small mammal distribution in forested communities. Sixteen separate variables were measured contemporaneously during five day live trapping periods (with twice daily marking and release of captures) concerning vertical and horizontal vegetation structure, vegetation composition, substrate and surface conditions, and illumination.

Simple correlations between 30 of 240 possible pairings of habitat variables from 125 trap stations were significant to very highly significant, though small. Though no measured variable correlated significantly with capture numbers including zeroes, *Peromyscus leucopus* captures correlated with soil moisture and *Tamias striatus* captures correlated significantly with foliage indices and illumination when respective zeroes were excluded.

Tests of descriptive statistics of variables show that animal occurrence in live traps is neither a Gaussian nor a uniform random process, in that differential use of sites can be shown for ground vegetation cover, shrub cover, tree basal area, and leaf litter cover and depth values, and that values for most variables for sites used were significantly skewed and significantly platykurtic, contradicting the "optimum habitat use" paradigm.

Implications of these findings for analysis and interpretation of multivariate habitat data about small mammals are discussed and a new explanatory paradigm using frequency distributions is proposed.

The Big Walnut Great Blue Herons. J. DAN WEBSTER and BRETT E. WHEELER, Hanover College, Hanover, Indiana 47243.——Great Blue Herons in 1982 occupied 31 nests at the Big Walnut Natural Area in Putnam County and fledged approximately 27 young. Observations indicated that during the period when they were incubating and caring for young in the nest, adults flew out and returned at varied times, not in groups, and in several directions. Evidently their feeding areas were dispersed.

Descriptive Study of the Response Pattern to Urinary Conspecific Odors by Female Golden Hamsters in a Home Cage Environment. CATHERINE ZMACHINSKI and ROBERT B. FISCHER, Department of Psychological Science, Ball State University, Muncie, Indiana 47306.——This study was conducted to determine the female hamsters (*Mesocricetus auratus*) response to potential intruder odors as a function of estrous state and dominance status in a home cage environment. Females were individually housed and tested in 24″ x 14″ x 9″ plastic cages. They were simultaneously presented with three airborne urinary oderants and saline control. Sources for urine samples were males differing

in dominance status and diestrous females. Results demonstrate that females' degree and pattern of response to conspecific urinary odors varies as a function of estrous state and dominance status. In general, dominant females are less active and apparently less attracted to strange conspecific odors on the day of estrous than diestrous. In contrast, submissive females do not show such changes in response to stimuli as a function of estrous state. To male odors, dominant females showed less attraction while in estrous than diestrous and demonstrated no preference for dominant or submissive male urinary cues. An opposite pattern was seen with submissive females. Dominant females would approach strange female urinary stimuli more frequently when in diestrous and did so more than submissive females. Submissive females showed no such changes in responding.

When in diestrous the dominant female approaches conspecific odors more frequently and for longer periods than does the submissive female. The submissive female appears to be more affected by the odors, showing greater activity towards all stimuli. Behavioral responses to male stimuli were contrary to previous findings on attractivity of female hamsters to urinary odors tested in small, novel enclosures. Dominant females showed less attractivity to male stimuli when in estrous than submissive females. And, there was little differentiation of male dominance status by either dominant or submissive subjects. Though preliminary, these results do suggest that response patterns to conspecific urinary odors may vary with the testing apparatus.

Hibernacula of the Endangered Indiana Bat in Indiana

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A total of 37 visits was made to 27 caves (known or potential *Myotis sodalis* hibernacula) during the 3 winters between autumn 1980 and spring 1983. Of the caves visited, 15 were used as hibernacula by *M. sodalis*. The 2 Priority 1 hibernacula, both of which are protected, contained 79% of the state's wintering population. Ray's Cave contained 11% of the population. This population has increased markedly in the past 8 years. One reason for this may be a reduced pressure on the bats by the scientific community. Despite this increase, and also because of it, this cave needs to be protected. Three other caves, Wyandotte, Grotto, and Coon's, have also experienced increases in hibernating populations in the past several years. Wyandotte (the type local) is on state property. As a result of this investigation Grotto and Coon's caves have come under a landowner protection agreement with The Nature Conservancy. Population counts at other caves are provided so that interested groups, public or private, can make decisions on protection, and to provide a data base for analysis of long term trends. Protection of non-Priority 1 hibernacula is encouraged because of the extreme vulnerability of populations at the 2 Priority 1 caves.

Introduction

The Indiana bat, *Myotis sodalis*, was not recognized as a distinct species until Miller and Allen (6) delineated the taxonomy of the related species of *Myotis* with which it was confused. Historically, Wyandotte Cave, the type local, has housed the largest wintering population (7); however, 2 caves recently discovered (9) have larger populations. Ray's Cave has also historically contained a major portion of the known hibernating population in Indiana. Humphrey (4) reported the known populations of *M. sodalis* hibernating in 7 Indiana caves in 1975. He determined that 2 caves contained the majority of the state's population, and the 4 largest hibernacula contained 99.5% of the population.

The clustering behavior of this species makes it extremely vulnerable to natural catastrophe, human disturbance, and vandalism. Hall (3) documented the extirpation, by flooding, of a hibernating colony estimated at 300,000 in Bat Cave, Edmonson County, Kentucky. About 3,200 *M. sodalis* were killed by flooding of their hibernaculum in Wind Cave, Kentucky (2). Vandals killed about 10,000 *M. sodalis* in Bat Cave, Carter County, Kentucky, in 1961 (4). Similarly, vandalism has been reported to us from Ray's Cave in Indiana, and Humphrey (4) reported that "a bushel basket" of bats was killed by vandals in Little Mammoth Cave, Tennessee, in 1970.

In addition to vandalism, human disturbances from cave usage and visitation by biologists has led to precipitous declines at some caves. A 60% decline in the number of bats using Bat cave, Carter County, Kentucky was attributed to past repeated distur-

bance by biologists and cave visitation (4). A 95.5% decline occurred at Coach Cave, Kentucky after one of the cave's entrances was blocked and air flow restricted. Gating at Colossal Cave, Kentucky, and at Wyandotte Cave, Indiana also restricted air flow, and resulted in a decreased population of hibernating bats.

The vulnerability of the species to man-made perturbation and natural catastrophe, as a result of the winter clustering behavior and extreme aggregation in only a few hibernacula, led to its listing as a federal endangered species in 1966. A 28% decline of the population throughout the range occurred in the 15 year period from 1960 to 1975 (4). The Indiana Bat Recovery Team,[1] therefore, has decided that Priority 1 hibernacula (greater than 30,000 bats) should be censused only every other year, and in order to standardize population estimation, all Priority 1 caves will be censused by the same individual beginning during the 1982-1983 season. In addition, federal, state, and private organizations have begun to provide protection to major hibernacula.

Despite these admirable efforts, there is a great deal of benefit that can be accrued at *M. sodalis* caves that are not Priority 1 hibernacula. These hibernacula may be of particular importance should an unforeseen or unavoidable catastrophe occur at one or more of the Priority 1 hibernacula. Since little or no recent data exist on the number of bats utilizing 19 caves reported used by *M. sodalis* in Indiana (7), it was decided that the initial step in determining the importance of secondary hibernacula to the species was to census these hibernacula. This will provide a data base for the Indiana Department of Natural Resources, Natural Heritage Program, and others, for analysis of long-term trends. In addition, the current population numbers at the Priority 1 hibernacula (Twin Domes and Bat Wing caves) were determined in association with and in assistance to the U.S. Fish and Wildlife Service Indiana Bat Recovery Team. Cave temperatures were taken and the numbers of bats of other species were noted while conducting the censuses.

Materials and Methods

During the winters of 1980-1982 through 1982-1983, 27 caves were visited a total of 37 times. Locations of the caves visited can be found in Brack (1), allowing for future checks on non-Priority 1 and unprotected caves, so that long term trends can be observed. Mumford (7) listed 19 caves which have been occupied by *M. sodalis*; all but 2 of these were visited. Bear Cave, Crawford County could not be located. Later research indicated that the correct location may be Orange County. The caretakers of Boone Cave would not allow access to this cave.

The numbers of *M. sodalis* in small clusters were counted directly. In larger clusters, the size of the cluster was measured with a tape measure, and the number of bats was calculated at 300 bats per square foot (5). The numbers of bats of other species were usually counted directly, except that larger groups of *Myotis lucifugus* (little brown bats) were estimated by groups of 10. Temperatures were taken near large clusters of *M. sodalis* with a Schultheis quick recording thermometer. The hibernacula counts were compared to past records, determined from published accounts (4,8) and from unpublished records of Mumford.

Results

Myotis sodalis was found hibernating in 15 caves (Table 1). Two of these, Twin Domes and Bat Wing, are Priority 1 hibernacula on dedicated Indiana State Nature

1 Recovery Team

TABLE 1. *Bat hibernacula counts and cave temperatures.*

Cave	Date	M. sodalis	M. lucifugus	M. keenii	E. fucus	P. subflavus	**Temp. °C	Observer(s)
Twin Domes	27 Feb. 1981	98,250	0	0	0	0	—	JC, VB, AW
	28 Jan. 1983	70,750	—	—	—	—	—	RC, JC, VB
Bat Wing	8 Mar. 1981	29,960	1	0	0	11	4.4°	VB
	28 Jan. 1983	26,650	—	—	—	—		RC, VB, JC
Ray's	*15 Oct. 1980	1,920	—	—	—	—	—	RM, VB
	9 Mar. 1981	12,500	3,380	22	60	14	7.0-8.5°	VB
	13 Jan. 1982	11,822	799	0	95	10	0.6-1.4°	VB, AW
	12 Feb. 1983	13,475	1,834	1	85	14	4.0°	VB
Grotto	21 Feb. 1981	3,190	589	0	0	2	2.0°	VB
	29 Jan. 1982	2,692	1,090	1	0	44	3.6-4.9°	VB, AW
Wyandotte	27 Feb. 1981	2,152	6	0	11	2	—	JC, VB, AW
	29 Jan. 1983	4,550	—	—	—	—	—	RC, VB
Coon's	21 Feb. 1981	1,190	31	0	0	6	1.0-9.5°	VB
	29 Jan. 1982	550	12	0	1	5	6.8°	VB. AW
Buckner's	29 Jan. 1982	488	32	0	2	57	3.0°	VB, AW
Parker's Pit	31 Jan. 1982	400-500	—	—	—	—	—	MW
Saltpeter (Crawford Co.)	20 Jan. 1982	352	114	0	8	7	6.0°	VB, AW
River	12 Feb. 1982	104	170	2	4	65+	7.2°	VB, AW
Saltpeter (Monore Co.)	29 Jan. 1982	83	19	0	46	0	9.1°	VB, AW
Salamander	26 Feb. 1982	74	130+	0	0	21	—	AW
Clyfty	14 Jan. 1982	66	298	0	10	46	6.0°	VB, AW
Wildcat (Sheep)	20 Jan. 1982	29	332	0	0	30	8.1°	VB, AW
Endless	13 Jan. 1982	2	163	0	17	26	10.5°	VB, AW
Bronson's	12 Jan. 1982	0	0	0	0	3	10.5-12°	VB, AW
Twin	12 Jan. 1982	0	0	0	1	0	9°	VB, AW
Hamer	12 Jan. 1982	0	1	0	10	1	—	VB, AW
Donaldson's	12 Jan. 1982	0	0	1	25	3	—	VB, AW
Sullivan's	13 Jan. 1982	0	0	0	0	0	11.8°	VB, AW
(back entrance)	13 Feb. 1982	0	0	0	0	0	—	VB, AW
Donnehue's	*13 Jan. 1982	0	0	0	4	0	1.4-3.8°	VB, AW
	12 Feb. 1982	0	98	0	6	2	—	VB, AW
Bentz	21 Jan. 1982	0	16	0	8	24	5.8-7.4°	VB, AW
Quarry	21 Jan. 1982	0	0	0	0	1	—	VB, AW
Siebert's Well	20 Jan. 1982	0	0	0	0	0	—	VB, AW
Sharp Creek	20 Jan. 1982	0	0	0	0	0	—	VB, AW
Ranard School	13 Feb. 1982	0	0	0	8	0	1.2°	VB, AW
Salt's	26 Feb. 1982	0	33	0	6	12	—	AW

*Searches were cursory

**Temperatures were taken near *M. sodalis* when they were present, and shortly after the photo-zone when they were absent.

RM — Russell Mumford
JC — James Cope
RC — Richard Clawson
VB — Virgil Brack
AW — Anthony Wilkinson
MW — Michele Wright

Preserves. These 2 caves contained 79% of the state's population of hibernating *M. sodalis*. Ray's Cave contained the third largest population, with 11% of the hibernating bats in the state found there. The present population at Ray's Cave is up, as have been the 2 most recent censuses at Wyandotte, Grotto, and Coon's caves (see Table 2 for past populations). Buckner's Cave had a small but significant population of bats. Most other caves containing hibernating *M. sodalis* supported small popula-

TABLE 2. *Past populations and dates of census of caves utilized as hibernacula by* M. sodalis.

Cave	Date	Population	Source
Twin Domes	1976	100,000	Richter *et al.*, 1978
Bat Wing	1977	50,000	Richter *et al.*, 1978
Ray's	1952	2,700	Mumford and Whitaker, 1982
	1955	1,000	(same)
	1960	512	Humphrey, 1978
	1964	960	Mumford and Whitaker, 1982
	1965	3,200	(same)
	1969	600	(same)
	1970	1,300	(same)
	1975	2,000	(same)
		2,700	Humphrey, 1978
Wyandotte	1953	10,000	Mumford and Whitaker, 1982
	1955	500	(same)
	1960	980	(same)
		1,944	Humphrey, 1978
	1965	3,200	Mumford and Whitaker, 1982
	1970	1,000	(same)
	1974	1,900	(same)
Grotto	1960	200	Humphrey, 1978
	1969	80	Mumford, 1974
	1974	50	(same)
	1975	200	Humphrey, 1978
Coon's	1953	150	Mumford, 1974
	1960	9	Humphrey, 1978
	1974	70	Mumford, 1974
	1975	24	Humphrey, 1975
Buckner's	1952	500	Mumford and Whitaker, 1982
	1953	300	Mumford, 1974
	1954	400	Mumford and Whitaker, 1982
	1956	295	(same)
	1960	63	Humphrey, 1978
	1962	160	Mumford, 1974
	1974	300	(same)
	1975	345	Humphrey, 1978
Saltpeter	1953	22	*
(Crawford Co.)	1975	95	Humphrey, 1978
Saltpeter	1952	13	*
(Monore Co.)	1954	18	*
Clyfty	1954	9	*
Wildcat (Sheep)	1950	6	(collected) by L. P. Wood and R. F. Inger*
Bronson's	1948	1	(collected) by R. G. Prasil*
	1953	4	*
Donaldson's	1962	1	*
Sullivan's	1955	15	*
Donnehue's	1969	1	*
	1971	1	*
Bentz	1959	8	*
Boone	1962	1	*

* Unpublished data—R. E. Mumford

tions (Table 1). Parker's Pit Cave was reported to us by Michele Wright to contain 400-500 *M. sodalis*. This was the first reported use of this cave. The smallest number of *M. sodalis* found in any cave was 2, in Endless Cave. In general, caves with larger (400 bats or more) concentrations of bats were colder than caves occupied by few or no bats. Several caves which have had small populations of *M. sodalis* in the past contained no bats during these visits.

The numbers of bats of other species observed were relatively small. *M. lucifugus*

was common in only Ray's Cave. *Myotis keenii* (Keen's bat) was located on only 5 cave visits at 4 caves. *Eptesicus fuscus* (big brown bat) was found in several caves but was most abundant at Ray's Cave. *Pipistrellus subflavus* (eastern pipistrelle bat) was found at more caves than any other species, but was not numerous at any.

Discussion

It is apparent from these population counts that several non-Priority 1 hibernacula in Indiana should receive protection. Ray's Cave contains about 11% of the state's population of hibernating *M. sodalis*, but is not protected from human disturbance. Capture with a bat trap at Ray's Cave during spring and autumn swarming periods also produced large numbers of *M. keenii*, which is on the state's threatened species lists. Because of their secretive hibernating habits, they are only rarely seen during hibernacula visitation. The population of *M. sodalis* at Ray's Cave historically has varied between 1,000 and 3,000 bats (Table 2) while the current population is 3 to 4 times that number. It is felt that this population increase is due to a large reduction in the number of bats removed from the cave for biological research during the last 8 to 9 years. It has been related to us that until recently, hundreds to thousands of bats were removed yearly from Ray's Cave for research. This heavy harvest predates regular bat censusing at the cave. The accuracy of these reports is not verifiable, but it is consistent with and may represent a mechanism for the dramatic increase in recent years. Despite this increase, and also because of it, Ray's Cave should be protected during the season of hibernation (1 September-30 April) from random visitation.

Grotto and Coon's caves also have viable populations which logically should benefit by seasonal protection. As a result of the censusing done during this project, these 2 caves have come under a voluntary landowner agreement with the Indiana Natural Areas Registry (a cooperative undertaking between The Nature Conservancy and the Indiana Department of Natural Resources) to restrict winter visitation. The populations at both Coon's and Grotto caves are up since the last reported censuses of 1975 (4). The reasons for these increases are not known. They may simply be fluctuations of an intrinsic or unknown cause, or federal protection of the bats may be producing a positive effect on population numbers. There has also been a heightened awareness and subsequent modification of potentially disruptive actions by cavers in recent years. Since this group of individuals represents the major volume of human traffice in caves, and thus represents a major potential for disturbance to the bats, it is anticipated that their cooperation in avoiding disturbance to the bats would produce a positive effect. Even if some types of disturbance from uninformed individuals continues, a reduction of vandalism should benefit the bats.

The numbers of *M. sodalis* hibernating at a majority of the other caves visited were relatively small, and were comparable to numbers found there in the past. No *M. sodalis* were found at Bronson's, Donaldson's, Sullivan's, Donnehue's, or Bentz caves, although in the past bats have been found in them. Parker's Pit Cave, with a population of 400-500, is difficult to enter, thus reducing visitation and consequently disturbance. Saltpeter Cave, located on state forest land in Crawford County, has recently experienced some roof destabilization. Therefore, state personnel are recommending against visitation by most individuals. The 2 Priority 1 hibernacula are on state property and unauthorized entry is prohibited by federal law.

Summary

Hibernating *M. sodalis* were found in 15 of 27 caves visited during the period October 1980 to January 1983. The 2 Priority 1 caves housed 79% of the state's hiber-

nating population of *M. sodalis*. Prior to this study, only one non-Priority 1 cave, Wyandotte, was protected. Non-Priority 1 caves should be protected because of the extreme clustering habit of the species. Clustering increases the susceptibility of the species to natural and man-made catastrophes. Should a catastrophe occur at one of the state's Priority 1 hibernacula, a large percentage of the state's population would be lost. As a result of this study, 2 caves, Grotto and Coon's, have been protected by landowner agreement through The Nature Conservancy. The population at Ray's Cave has greatly increased over the past few years, and now harbors 11% of the state's hibernating population of *M. sodalis*. While this ranks as the third largest population in the state, the cave has no protection at this time. The population counts at the other caves will provide information on long term trends at these caves.

Acknowledgments

Field expenses were provided to Anthony Wilkinson by The Nature Conservancy and the Indiana Natural Heritage Program, Department of Natural Resources. Michele Wright provided information on the locations of some caves and reported a population of bats from Parker's Pit Cave. Richard Clawson reviewed the manuscript and Bobby Witcher was a constant source of inspiration. We thank numerous individuals who accompanied us on one or more cave trips, and the many landowners who allowed access to caves on their property.

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The Distribution of the Smoky Shrew, *Sorex fumeus*, and the Pygmy Shrew, *Microsorex hoyi*, in Indiana with Notes on the Distribution of Other Shrews

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Introduction

The presence of the Smoky Shrew, *Sorex fumeus*, and the Pygmy Shrew, *Microsorex hoyi*, in Indiana was first documented by Caldwell, Smith and Whitaker (1982). The presence in Indiana of these species was suspected based on the continuous nature of the physiographic ecological region from northern Kentucky to southern Indiana. *Microsorex* occurs from Alaska through Canada and into the United States as far south as Colorado and Georgia (Diersing 1980). *Sorex fumeus* occurs from southeastern Canada through the northeastern United States to the mountains of Georgia and west across two-thirds of Kentucky (Hall 1981, Caldwell and Bryan 1982). The ranges of the two species overlap extensively in the eastern United States.

The present study was undertaken to establish the distribution of *S. fumeus* and *M. hoyi* in Indiana and to gain additional information on the distribution of associated shrew species.

Methods and Materials

A total of 35 localities in 21 southern Indiana counties was trapped to indicate the presence or absence of *S. fumeus* and *M. hoyi*. Pitfall traps (1000 ml plastic disposable beakers with approximately one inch of water) were sunk along natural obstructions (i.e., logs, rock faces, etc.) in suitable habitat. An average of 19 cans (range 6-40) was used per site, left in place an average of 31 days (range 16-49) and checked periodically. Trapping effort totalled 29,967 trapnights. Specimens were prepared as study skins and skulls or as skulls only depending on their condition and were deposited in the Indiana State University Mammal Collection.

Results and Discussion

Total numbers of captures for each species were: 299 Short-tailed Shrews (*Blarina brevicauda*), 108 Smoky Shrews (*S. fumeus*), 98 Masked Shrews (*S. cinereus*), 73 Pygmy Shrews (*M. hoyi*), 76 Southeastern Shrews (*S. longirostris*), 69 Pine Voles (*Microtus pinetorum*) and 32 White-footed Mice (*Peromyscus leucopus*). The locations of 13 sites where *S. fumeus* was taken are indicated in Figure 1. Smoky Shrews occurred as far west as the Martin State Forest, Martin Co., as far east as the Clark State Forest, Clark Co. and as far north as the Morgan Monroe State Forest in Monroe Co. *Microsorex hoyi* occurred on 17 sites and occupied a similar but slightly greater range than *S. fumeus* (Figure 2). Western-most sites included the Ferdinand State Forest in Dubois Co. and a site 6 mi W of Spencer, Owen Co. while northern and eastern boundaries were the same as those for *S. fumeus*. The two species occurred together on eight sites, *M. hoyi* occurred alone on nine sites and *S. fumeus* occurred alone on five sites.

FIGURE 1. *Sites where Smoky Shrews,* Sorex fumeus *have been taken in Indiana (Solid circles). Hollow circles indicate that trapping occurred during this study, but no Smoky Shrews were taken.*

FIGURE 2. *Sites where Pygmy Shrews,* Microsorex hoyi *have been taken in Indiana (Solid circles). Hollow circles indicate that trapping occurred during this study, but no Pygmy Shrews were taken.*

Both *s. fumeus* and *M. hoyi* are restricted primarily to the unglaciated region of Indiana. The Illinoian advance of Pleistocene glaciation extended as far south as indicated in Figs. 1 and 2 (Wayne and Zumberge 1965) and few sites lie outside this boundary. Of 22 sites that harbored either Smoky Shrews or Pygmy Shrews, 17 occurred within the Illinoian glacial boundary. Four of those sites that occur on glaciated areas are very close to the boundary (6 mi W of Columbus, Bartholomew Co.; Clark State Forest, Clark Co.; 2 mi N of Whitehall, Owen Co.; Jackson-Washington State Forest, Jackson Co.). An Owen Co. site 6 mi W of Spencer represents the location farthest from the glacial boundary. *Microsorex hoyi* alone was taken on three of the five sites outside the glacial boundary while both *M. hoyi* and *S. fumeus* were taken on the other two.

The slightly more extensive range of *M. hoyi* would be expected based on the known habitat tolerances of the two species. *Sorex fumeus* is restricted to shady, damp coniferous or hardwood forests and is seldom found in dry woods (Hamilton and Whitaker 1979). *Microsorex hoyi* is known to occur in a variety of habitats including bluegrass pasture, mature woodland, marsh, brushland, riparian woodland, bogs and rich mesophytic forests (Buckner 1966, Long 1972, Caldwell and Bryan 1982).

Habitat preferences for *S. fumeus* and *M. hoyi* in Indiana may be generally described as mature woods in moist ravines or on wooded slopes with many downed logs and a deep humus layer. Sugar maple (*Acer saccharum*) dominated most sites where *S. fumeus* occurred. Sandstone or limestone outcrops were present on several sites and Christmas fern (*Polystichum acrostichoides*) was a common associate. Dominants on sites where *M. hoyi* was taken were somewhat more variable. In addition to those sites occupied by *S. fumeus*, habitats including dominants of American beech (*Fagus grandifolia*), Red oak (*Quercus rubra*), Chestnut oak (*Q. prinus*) and hickories (*Carya* spp.) harbored Pygmy Shrews. Further trapping in other habitats within the unglaciated region may indicate that Pygmy Shrews occupy other habitats as well. Soil moistures varied from moist to dry for *M. hoyi* but no *S. fumeus* were taken on dry sites. On sites where *M. hoyi* co-occurred with *S. longirostris*, Pygmy Shrews occupied upper elevation often sloping habitats while Southeastern Shrews occurred on lower elevation or more bottomland habitats along creeks.

Two other shrews, the Short-tailed Shrew (*Blarina brevicauda*) and the Southeastern Shrew (*S. longirostris*) were commonly associated with *S. fumeus* and *M. hoyi*. *Blarina* occurred on all but five sites and was the dominant small mammal on 14 sites. *Sorex longirostris* occurred on 18 sites throughout the unglaciated region and to the west (Fig. 3). *Sorex cinereus* occurred on three sites (Figure 3). Two of these sites in the eastern part of the state (Jennings Co. and Ohio Co.) yielded only Masked Shrews while both *S. cinereus* and *S. longirostris* occurred on a site at Freeman, Owen Co. French (1980) reported that the two species are usually mutually exclusive, being trapped together on only three previous occasions in Indiana. Where they co-occur in Vigo Co., the two species occupy distinct habitats, *S. cinereus* in the glacial floodplain of the Wabash River and *S. longirostris* in the surrounding uplands. Indications from the present study are that a similar situation on a larger geographic scale may explain the occurrence of *S. longirostris* in unglaciated upland sites and *S. cinereus* on glaciated lowland sites. Mumford and Whitaker (1982) state that *S. longirostris* probably occupies much of the southern two-thirds of Indiana while *S. cinereus* is especially common in the northern half of the state although it does occur as far south as Posey and Spencer Counties (Figure 3). It is apparently absent in the south central unglaciated portion of the state, the area in which *S. fumeus* and *M. hoyi* occur.

Studies are now being completed on the food habits, ectoparasites and interrelationships of these species and will be considered in a future paper.

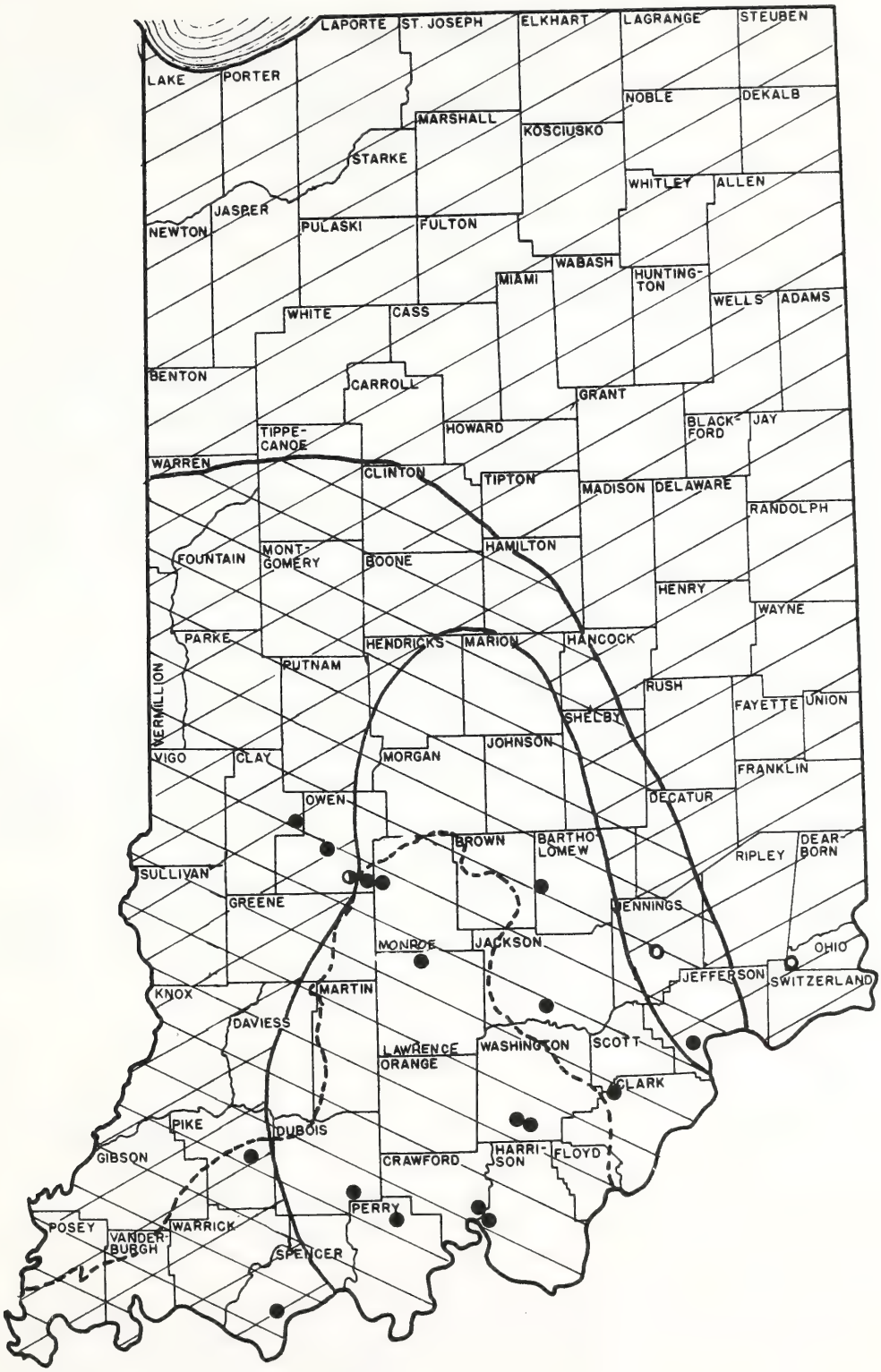

FIGURE 3. *Ranges of Southeastern shrew,* Sorex longirostris *(cross-hatching slanted down to the right), and Masked shrew,* S. cinereus *(slanted down to the left). Solid circles indicate capture sites for* S. longirostris, *hollow circles indicate capture sites for* S. cinereus *and half-shaded circle indicates captures of both species.*

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Collections of Planktonic and Interstitial Marine Rotifers from Puerto Rico

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Introduction

Investigations of the fauna of coral reefs have never carefully examined the microfauna, and specifically the rotifer fauna, in a detailed manner. While a few reports of plankontic marine rotifers exist (reviewed in 2) only a few have been oriented to the interstitial (= psammon) rotifers (reviewed in 2). Part of the reason for this lack of information on marine rotifers stems from the impression that they are, with rare exception, a group of exclusively freshwater invertebrates. Also, they are difficult to isolate from planktonic and interstitial samples. This investigation reports on collections made off the coast of Puerto Rico in 1977 aimed specifically at collecting marine rotifers.

Study Site and Methods

Five marine sites off the coast of Puerto Rico were selected for study (Figure 1). These included a southern shore coral reef, a northern shore coral reef, Phosphorescent Bay, a mangrove cay, and northern shore coral sand beach. Sampling was completed during the daylight hours at all of the sites, with the exception of Phosphorescent Bay, which was sampled at night.

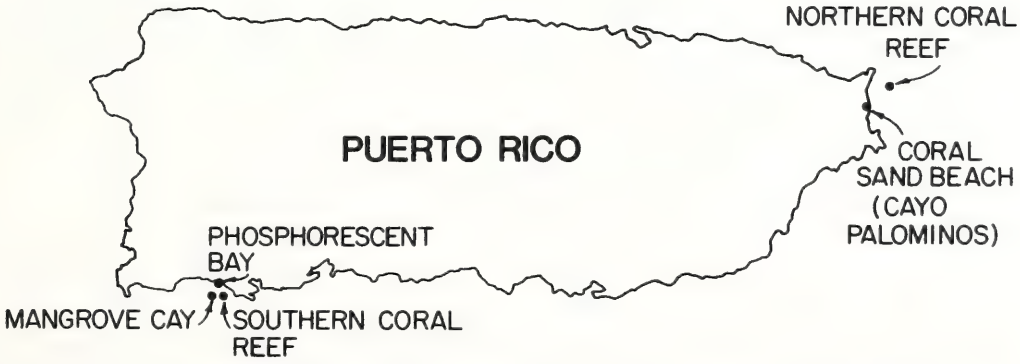

Figure 1. *Location of Marine Sampling Sites off the Coast of Puerto Rico*

Continuous trawls were made at each site using a 125 mesh (No. 25) nylon plankton net. Concentrated plankton were preserved in 10% formalin solution after having been anesthetized with benzamine hydrochloride.

Quantitative sediment samples were taken at four sites: southern shore coral reef, northern shore coral reef, mangrove cay and northern shore coral sand beach. A pvc tube with a cross section of 1 cm^2 was forced into the substrate to a depth of about 10 cm. Four replicate samples at each site, consisting of 5-10cm^3 of coral sand each, were collected in stoppered glass tubes. Samples were extracted using the magnesium

TABLE 1. *Planktonic Rotifers Identified at Marine Sites in Puerto Rico*

	Site				
Species	Southern Reef	Northern Reef	Phosphorescent Bay	Mangrove Bay	Coral Sand Beach
Argonotholca foliacea		x		x	
Brachionus plicatilis	x	x	x	x	x
Keratella cochlearis	x	x			x
Lecane cornuta	x	x			
Notholca striata			x	x	

chloride anesthetization technique (1). No interstitial samples were taken at or beneath the black sulphite layer of sediments at each of these sites.

Water samples (both open water and interstitial water) were collected for salinity determination. Salinity was estimated using an American Optical Goldberg Salinity Refractometer. For study and taxonomic identification of individual rotifers the mastax was mounted in polyvinyl-lactophenol (4) and examined microscopically.

Results and Discussion

Table 1 indicates the planktonic rotifers found at each site. Since these were qualitative plankton tows it is uncertain how abundant each of these species were. The euryhaline *Brachionus plicatilis* was the only species found at all of the sites. The other four species were collected at two or three of the five sites. Table 3 indicates the salinity of the open-water collecting sites at the time of collection. The values range from 22-32 °/oo salinity and are probably the highest reported salinities noted with the occurrence of several of these species. Given the limited nature of the sampling it is uncertain whether these salinities represent extremes for these sites or whether they are relatively constant. Phosphorescent Bay, with a low value of 22 °/oo must certainly experience considerable fluctuation due to freshwater inflowing to the bay.

TABLE 2. *Interstitial Rotifiers Identified at Marine Sites in Puerto Rico*

	Site			
Species	Southern Reef	Northern Reef	Mangrove Cay	Coral Sand Beach
	Organisms/cm³ substrate; mean value of four replicate samples			
Aspelta clydona	3.0	1.3	0	11.5
Aspelta reibischi	0	1.3	0	11.0
Colurella adriatica	5.3	0	1.3	0
Colurella colurus	0	0	0	1.6
Encentrum cruenatum	4.0	2.5	3.0	2.5
Encentrum marimum	10.5	8.5	3.3	15.5
Encentrum rousseleti	2.0	0	0	8.0
Encentrum simillimum	0	0	0	2.6
Encentrum striatum	3.3	0	0	0
Encentrum villosum	0	6.6	1.5	0
Euchlanis dilatata	0	1.5	0	0
Paradicranophorus hudsoni	0	2.5	0	3.6
Proales reinhardti	3.3	1.0	3.0	6.3
Proales halophila	5.5	3.6	1.5	2.5
Rotaria citrina	1.3	5.0	7.6	0

TABLE 3. *Salinity of Marine Sites in Puerto Rico*

Site	Salinity °/oo	
	Openwater	Interstitial
Southern reef	29	32
Northern reef	32	30
Phosphorescent Bay	22	—
Mangrove Cay	26	28
Coral sand beach	30	30

The quantitative analysis of interstitial rotifers at four sites is shown in Table 2. These samples showed a much greater species diversity than those from the associated open water areas (plankton samples). All of these rotifers have been reported by Thane-Fenchel (5,6) or Tzschaschel (7,8) from northern European marine waters. A major difference, however, is the salinity of the interstitial or surrounding water in the areas in which they collected. The Puerto Rican samples were collected from sites that were at or approach full-strength seawater (greater than 30 °/oo S). Furthermore the rotifers appeared somewhat more abundant than those found by Thane-Fenchel (5). No particular pattern of occurrence was apparent at each of the sites that allowed them to be clearly distinguished from each other. There were, however, some differences in abundance between sites that are worth noting; comments on food habits are also included.

Members of the genus *Aspelta* were relatively abundant in the loose coral sand (32 °/oo S) and could be seen feeding on other rotifers. Abundant mastax trophi from other interstitial rotifers were noted in their guts. *Colurella* species were found irregularly in low concentrations and showed guts full of diatoms and bacteria. The genus *Encentrum* was well represented in the interstitial samples. *E. cruenatum* and *E. marinum* were ubiquitous. All *Encentrum* showed a mixed stomach contents consisting of diatoms, ciliates and nematodes. *Paradicranophoris hudsoni* was found at two sites. In both cases the animals' guts were filled with the pennate diatoms that were noticeably abundant in the interstitial samples. The two *Proales* species were ubiquitous. Their guts were filled with mixed diatoms and a few dinoflagellates. *Rotaria citrina* represents the only bdelloid rotifer collected during this study. Occurring in some abundance at these sites, its gut contents could not be distinguished.

This localized study demonstrates the existence of marine rotifers, in at least modest diversity, in marine planktonic and interstitial habitats that approach full-strength seawater. Previous work in these habitats has undoubtedly failed to isolate these rotifers owing to the special care needed (e.g., fine net size, special extraction procedures) for delicate organisms present in small numbers. While the concentration of interstitial rotifers reported for freshwater is in the range 10-100 rotifers per cm^3 sand (3) some of my samples did exceed this lower limit at a site or two. A future seasonal observation at each of these sites might show populations that increase into the range usually thought only to occur in freshwater. While Tzschaschel (7) notes the dorsaventral flattening, existance of tubular toes, complicated joints of the toes, and enlargement or doubling of the foot glands as rotifer adaptations to the interstitial environment, Thane-Fenchel (5) notes that the degree of rotifer adaptation is slight compared to other marine interstitial microfauna. This is a possible reason for the low abundance of rotifers noted in marine interstitial samples.

Thane-Fenchel (5) has shown, in laboratory experiments, that rotifers maintained at 20 °/oo S had high reproductive potentials. Whether or not this high reproductive potential is maintained at higher salinities is not known. She did, however, show that

many species were able to tolerate the salinity range 0-32 °/oo in the lab, while field collections showed a decrease in number of species with increasing salinity. All of the rotifers collected in this study would be considered by many zoologists as euryhaline freshwater species. Since the rotifers are considered a limnic element in the marine fauna it is still unclear whether their limited abundance in the marine environment may have a morphological or physiological (e.g., osmoregulatory capacity) basis.

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The Occurrence of the Freshwater Medusa *Craspedacusta sowerbyi* Lankester in Spicer Lake, Saint Joseph County, Indiana

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Introduction

Craspedacusta sowerbyi Lankester (Hydrozoa: Limnomedusae) is a freshwater jellyfish first reported in England from 1880 (5). It probably has an oriental origin (2). Many authors have reported its occurrence in the United States, with most reports centered in the northeastern quarter of the United States (east of the Rocky Mountains and South of the 43rd parallel) (reviewed in 1,2,7 and 8). Particular Indiana sitings were reviewed by Lytle (6). Only a few of these sitings were in natural bodies of water: Elkhart County (Heaton Lake, 1951; Boss Lake-Crandall's Pond, 1918-24), Noble County (Diamond Lake, 1-52), Kosciusko County (Syracuse Lake, late 1920's, early 1930's; Winona Lake, late 1920's, early 1930's), and Marshall County (Myers Lake, 1952-55, 1957). The remainder were in reservoirs, gravel pits, limestone quarries, or other artificial impoundments.

Of the total of 17 Indiana records, six have been in artificial lakes, six in quarries or gravel pits, while only five have been reported from natural lakes (6). In reviewing North American reports for the medusa relatively few are from natural lakes (1,7).

While collecting plankton in Spicer Lake in June, 1983 I first noted the appearance of the *Craspedacusta* medusa. Spicer Lake is a 2 hectare kettle lake with a maximun depth of 6.1 m located in northwestern Saint Joseph County, Indiana (3). The lake is bordered by a uniform floating mat of vegetation, 4 to 8 m wide, that consists primarily of the yellow pond lily *Nuphar advena* and swamp loosetrife *Decodon verticillatus* var laevigatus, with spotty distributions of dodder, *Cuscuta gronovii*, bladderwort, *Utricularia*, and hornwort *Ceratophyllum demersum* in the mat.

This paper reports on weekly collections made during June, July and August, 1983 to determine the concentration of the medusa present in Spicer Lake. Additional information on water chemistry and plankton are also reported to provide possibly useful information on the conditions that support the jellyfish population in Spicer Lake.

Material and Methods

Medusae were collected by a gentle vertical tow with a No. 20 plankton net along the floating mat of the lake at weekly intervals from June 13 to August 26, 1983. All samples were collected between 0900-1200 hours. Samples of the floating mat were also collected in an attempt to locate polyp stages of *Craspedacusta*. Water samples were collected for physical and chemical analysis using an alpha water sampler. The temperature, dissolved oxygen, and pH of these water samples were determined using standard methods (9).

Results and Discussion

Medusae were only collected on June 13, June 20, June 28, July 12, and July 18. No medusae could be located on July 6, July 26, August 2, 10, 17, or 26. Concentrations were estimated at between 1-3 medusae/m^3 in all of these collections. Higher

concentrations, noted on each of the above dates, were found on the inshore bottoms where medusae lay, pulsing slowly, in patches of the filamentous algae *Spirogyra* and detritus. Repeated samplings showed no medusae present in Spicer Lake in early or late July or during the month of August.

Examination of 616 of the medusae showed that 603 were female while 13 (including a few from each sampling date) were male. Almost all field reports indicating sex have indicated that the male and female medusae are rarely reported together (1,7). Lytle (7) and Acker and Muscat (1) noted only three and two reports, respectively, of the cooccurrence of male and female medusae in the United States.

The polyp of *Craspedacusta* is microscopic, sessile and difficult to collect. Despite repeated collection of available substrates at Spicer Lake no polyps could be found. Their presence is almost certain, since they must precede the medusae in the life cycle of *Craspedacusta*. Since the polyp will not grow where there is heavy sedimentation or on surfaces with heavy growths of algae (1) this may explain the difficulty in detecting them in Spicer Lake. A large growth of *Spirogyra* and *Oscillatoria* was present on most surfaces throughout the sampling period.

The medusa has been known to be planktivorous for a number of years (1,4). Medusa stomach contents indicated that they were feeding on the zooplankton roughly in proportion to their abundance in Spicer Lake. The plankton (and hence the medusae gut contents) showed high concentrations of cladocerans (*Bosmina longirostris, Daphnia retrocurva*), copepods (*Diaptomus oregonensis*, mixed nauplii), and rotifers (*Filinia* sp., *Asplanchna priodonta, Keratella cochlearis, Polyarthra vulgaris*, and *Synchaeta* spp.) during the June to August sampling period. Medusae gut contents also showed the presence of the benthic depterans *Tendipes* sp. and *Chaoborus* sp., two genera noted by Dineen (3) as being abundant in benthic samples from Spicer Lake. *Craspedacusta* does not appear to be a selective feeder on planktonic or benthic invertebrates.

Temperature and other physico-chemical factors have been suspected of affecting the appearance of medusae in a particular body of water (1). While some waters regularly produce medusae year after year in the summer and autumn, their appearance in other locations seems unpredictable. The appearance of *Craspedacusta* medusae in June and July represents relatively early reports for Indiana (6) where they are usually located between late July and October. However, surface water temperatures for Spicer Lake from June to August, 1983 ranged from 20 to 24 C, falling within the optimal temperature range (19-30C) reported in the literature (1) for the medusa. Dissolved oxygen in Spicer Lake remained uniformly high in the water column throughout the study period (range 8.8 to 9.0 mg/1). The acidic pH was also relatively stable, being in the range 6.4 to 6.8 from June through August. This may represent the lowest recorded pH in which *Craspedacusta* medusae have been collected. Reviews of the worldwide reports indicate that *Craspedacusta* has not been found in bogs and generally is found in distinctly alkaline environments (1,7). Obviously the lower range pH tolerance of this species has been underestimated.

The disappearance of medusae in early July and my inability to detect them in late July and August cannot be explained. Throughout the sampling period the measured variables (abundance of zooplankton prey, temperature, dissolved oxygen) seemed to be in the optimal range based on literature values from other sites in North America. These new data corroborate earlier lists of conditions favoring the appearance of *Craspedacusta* populations. However, this *Craspedacusta* medusae siting is distinguished from many earlier North American and Indiana reports by: 1) the low pH of the lakewater habitat, 2) appearance of both male and female medusae in the population,

3) occurrence in a natural, undisturbed bog-like environment, and 4) the early seasonal appearance (June vs. previous reports of August) for northern Indiana lakes.

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The Pleistocene Vertebrate Collection of the Indiana State Museum with a List of the Extinct and Extralocal Pleistocene Vertebrates of Indiana

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Introduction

In 1869 the Indiana General Assembly established a Department of Geology and Natural Science within the State Board of Agriculture. It was headed by the State Geologist, who, in addition to making a geological survey of the State, was also to maintain a "cabinet" for the collection, identification and exhibition of "specimens of the ores, building stones, clays . . . quadrupeds, birds, fishes . . ." and other items of the natural history of Indiana and surrounding states and countries (7). The "cabinet" was first housed in the "old" and later the present State Capital building in Indianapolis. In 1919 the office of the State Geologist became known as the Division of Geology (within the Department of Conservation), and the "museum" collections were shuffled from room to room, resulting in damaged and lost specimens. Between 1926 and 1930 the collections were placed into storage in the basement (31; 32; 75; Logansport, Ind. Pharos-Tribune, Nov. 20, 1926). By the 1940's the Museum occupied an end of the basement, with two-thirds of its collections stored in crates and boxes in basements of other State owned buildings; records were chaotic, with few entries since 1926 (70). In 1945 the Division of Geology (now the Geological Survey) relocated on the Indiana University campus, Bloomington, and the Museum specimens remained in Indianapolis within the Division of State Parks (7). Though administrative interest in the Museum rose in 1945 and 1958 (75), the collections were again placed into storage in 1960 (74; 75). With demolition of the State House "Annex" pending in 1960, much of the geological collection (including Pleistocene bones) housed in its basement was moved into the State warehouse on Kentucky Avenue (74). Warehouse storage space became filled, and the remaining geological collections were to be left in the "Annex" to be disposed of by the wrecking contractor (letter, R. D. Starrett to R. H. Shaver, Nov. 21, 1960). Personnel from the Indiana Geological Survey, thus informed, salvaged on two trips the visible fossils from the "Annex" where the "floor of the storage room was a four-to-six-inch sea of fossil and a few other geologic specimens, labels, and containers . . ." (letter, R. H. Shaver to R. D. Starrett, Feb. 27, 1961; letter, W. J. Wayne, June 1, 1983). Wayne had seen no fossil bones among the Survey salvaged specimens. Starrett related (oral communication, Nov., 1983) that all materials had been removed from the "Annex" before it was demolished. Even at the warehouse "boxes appeared to have been opened by unauthorized persons and objects disappeared" (74). In 1967 the Museum relocated in the former Indianapolis City Hall, its present location. Around 1970 the Division of Museums and Memorials was created, with a mandate "to preserve, exhibit and interpret the cultural and natural history of Indiana for present and future generations" (75). Collections and staff have grown and exhibits have proliferated. It was not until 1982, however, that the natural history collections were fully transferred from warehouse storage into the Museum.

Little has been published upon the content of the State Museum collections. Thompson (1889) published a list of catalogued specimens (primarily of invertebrate fossils, modern mollusks and building stones) (77). The Pleistocene vertebrate remains received an excellent description by Hay (1912), in a paper still widely referred to today (22).

Cope and Wortman (1885) had described Indiana specimens supplied by the State Geologist, but it is not clear if they were part of the State "cabinet" collection (9). Lists of Museum acquisitions appeared in the first through fourteenth Annual Reports of the Department of Conservation (W. N. Logan, 1920-1932).

Natural history collections of the Museum are now being curated, and their importance assessed. The Pleistocene vertebrate remains form the basis of this paper. Unpublished records of especially Mastodons and Mammoths are presented, with descriptions of the remains, indicating their availability as comparative materials for future investigations.

Methods

Matching records to specimens was often difficult, it not impossible. Records prior to 1967 are incomplete. A few accession logs and a list from the 1923-1932 period supplied most of the information on specimens. Several systems of cataloguing had been used (often with duplicated numbers), and specimens were usually unmarked, or marked with numbers for which there was no data. Several specimens, however, did have labels affixed. Some specimens could be matched with their descriptions in Hay, 1912 and 1923 (22;23).

Remains of individual animals were grouped, judging by preservation, color, similarity of impacted sediments, period of growth, size and preservatives formerly used. Fractured and damaged bones were reconstructed with epoxy (Elmer's Super-Fast, E609). Mammoth teeth had dried out, with lamellae often separated at the brittle cementum; these, and the Mastodon teeth, were reconstructed with white glue (Elmer's). Ancient bones and especially teeth need to be stored in a humidified atmosphere (C.T. Madden, written commun., May 21, 1981).

Several preservatives have been used on the bones. The Stroh Mastodon bones (71.983.73) had been coated with a hard, dark finish. These have now split, exposing the crumbling interiors; they need further conservation. The Waterloo Mammoth (71.967.22) had been coated with an Alvar-acetone solution, and the Reeker Mastodon (71.976.36) bones soaked in a solution of white glue and water; all appear hard and well preserved. The fossil Black Bear materials (71.981.14) had been reconstructed with white glue (Elmer's), and soaked in progressively stronger solutions of polyeurythane (in mineral spirits); they are exceptionally hard and durable. The Kolarik Mastodon materials (71.980.50) were saturated with polyethylene glycol ("Carbo-wax"), and freeze-dried (12); they are in excellent, natural-appearing condition. Bones from the Place Mastodon (71.983.74), stored for a year before being donated to the Museum for conservation, were soaked in "Carbo-wax" and freeze-dried. Some bones preserved well, but others with progressive disintegration were only stabilized or displayed a "flaky" outer surface, some due to shrinkage. The Swanson/Reichart Mammoth bones (loan) were soaked in "Carbo-wax"; they appear to be stabilized, and some bones have dried hard.

The Mastodon/Mammoth teeth, reconstructed with white glue, will be impregnated with polyeurythane in a vacuum chamber. Many of the bones, reconstructed with epoxy, will be soaked in glyptol and acetone, a method currently used at the Field Museum of Natural History, Chicago (oral communication, William Simpson, Chief Preparator, Geology Dept., Jan. 5, 1983). New catalogue numbers are now affixed to specimens and all known data recorded. All of the bones and teeth were measured, with some of the data presented in Tables 1,2, and 3. Mammoth teeth were measured, following the methods of Maglio (43).

TABLE 1. Mammut americanum *tooth measurements, ISM collection (mm.)*[1]

CAT#	Placement	Length	Width	Maximum width across: Protoloph(−id)	Metaloph(−id)	Tritoloph(−id)	Tetartoloph(−id)
71.981.60	LM3	181+(mx.184)	ca. 101	102+(mx.107)	99+(mx.104)	98	ca. 84
71.981.61	LM3	160	93	93	92	81	66
71.981.62	LM3	168	ca. 100	e 99+	—	90	78
*71.981.91	LM3	154	96	96+(mx.98)	95	e 84	70
*71.976.36.1	LM3	203	106	102	103	104	94
*71.967.41	RM3	185	108	100	107	105	82
71.981.66	RM3	191	97	92+(mx.95)	95	90+(mx.92)	85
71.981.68	RM3	—	115+	—	115	—	—
71.983.64	RM3	—	104+	e 100	104	—	—
71.981.63	LM2	115+(mx.118)	93	—	91	e 91 (mx.93)	
71.981.65	LM2	—	ca.97(mx.99)	90	ca.95(mx.98)	—	
71.981.59	LM1	100+(mx.102)	78	ca.74	77	76	
*71.981.70	Lm3	197	ca.100(mx.102)	e 95(mx.97)	—	e 97 (mx.100)	—
71.983.120	Lm3	117	87	81	89	86	75
71.981.64	Rm3	194	—	—	—	—	89+(mx.92)
71.983.62	Rm3	199	97	89	97	98	90
71.981.67	Lm2	110	86	—	82	88	
71.983.63	Rm2	—	85	—	85	—	
*71.981.94.1	Lm1 (or dp4)	87	64	59	64	63	

1. Terminology from Saunders (71);*, documented specimen; e, estimate; mx, maximum estimated measurement.

TABLE 2. Mammuthus *tooth descriptions, ISM collection (measurements in mm.).*[1]

Cat#	Placement	LF	ET	LT	P	NOP	L	W
71.981.50	LM3	8.8	1.79	8.98	?+19	14	241+	90+ [6]
71.981.35	RM3	9.6	1.71	7.80	x24x	21	296	103 [5]
71.981.48	RM3	8.0	1.63	7.88	?+23	?+17	280+	93+ [9]
*71.968.83.55	RM1(or DP4)	9.8	1.70	7.83	x10	x10	129	81 [6]
71.981.49	LDP4(or M1)	12.1	1.30	4.68	x12x	x8	118	60 [7]
71.981.51	DP4(or M1)	10.0	1.40	—	x9+	3	—	62 [8]
*71.981.36	Lm3	8.2	1.40	7.3	24	17	339	106 [15]
71.981.34	Rm3	8.2	1.92	7.8	x23	x14	317	105 [15]
*71.981.45	Lm3	6.9	1.71	8.59	—	ca.18	—	100+ [7]
71.981.37	Lm2	8.4	1.44	6.58	x16	x6	223	73 [14]
*71.981.42	Lm3	9.2	1.27	—	x10+	ca.12	—	92 [9]
71.981.47	Rm2?	8.8	1.47	6.62	—	—	—	—
*71.981.38	Rm1(or m2)	6.6	2.03	9.26	+11x	+8	+188	77 [V]
71.981.52	Rm1(or m2)	9.0	1.52	6.84	—	10+	—	67+ [9]
71.981.53	Lm1(or 2,3)	8.9	ca.1.62	—	—	—	—	—
71.983.68	Lm1(or 2,3)	9.8	1.56	7.37	—	—	—	74+ [5]
71.981.39	Lm1	7.1	2.28	10.35	x12x	x12x	196	ca.78 [6]
*71.981.40	Rdp4(or m1)	11.9	1.09	4.32	x10+	ca.6	109+	59 [9]
71.981.43	Ldp3	10.4	1.14	6.48	x6x	x6x	69	53 [4]
71.981.41	?L molar	5.6	3.14	10.29	—	—	—	—
71.981.46	molar	5.6	2.23	8.63	—	—	—	—

1. LF, Lamellar Frequency (no. plates /100 mm.: average of 4 measurements from apex and base, lingual and labial sides); ET, Average Enamel Thickness (perpendicular to enamel surface); LT, Average Lamellar Thickness on Occlusal Surface; P, Number of Plates (x, indicates small terminal folds fused to the base of true plates; +, indicates incomplete specimen); NOP, Number of Plates within the Occluded Portion; L, length (perpendicular to average lamellar plane); W, Maximum Width (taken at plate indicated by superscript: plates numbered from front in Arabic, from rear in Roman numerals); measurement criteria from Maglio (43); *, indicates documented specimen.

TABLE 3. Mammut americanum and Mammuthus *sp., selected postcranial measurements (mm.).*[1]

	Mammut americanum[2]				*Mammuthus* sp.[3]		
	K-----	S----------	P----------	R	C1--------	S/R------	Pr
Tibia							
Total length----------	626	687+ mx.697	653	—	922	743	649
Proximal end, transverse width (normal to plane of posterior edge of femur facets)----------	254	255	235	—	292	258	194+ mx.201
Proximal end, anteroposterior depth (perpendicular to plane of posterior edge of femur facets)-----	205	189	176	—	232	—	169
Distal end, transverse width--------	187	193	187	—	239+ mx.245	—	171
Distal end, anteroposterior depth (normal to posterior edge)----------	140	149	151	—	193	—	132
Least transverse width of shaft-----	99	93	95	—	134	108	105
Least circumference of shaft--------	300	290	292	—	384	330	285
Fibula							
Greatest Length----------	595	661	—	—	—	—	605+ mx.614
Proximal end, greatest antero-posterior diameter----------	83	87	—	—	—	—	54+
Distal end, greatest antero-posterior diameter----------	134	144	—	—	—	—	97
Middle of shaft, greatest antero-posterior diameter----------	55	60	—	—	—	—	48
Middle of shaft, transverse diameter----------	30	31	—	—	—	—	24
Femur							
Greatest length ----------	1079	1104	—	—	—	—	—
Transverse diameter of proximal end, from outer face of greater trochanter to inner side of head, normal to long axis of shaft--------	343	392+	—	—	—	—	—
Greatest anteroposterior diameter of head----------	172	185	—	—	—	—	—
Least transverse diameter of shaft----------	146	166	—	—	—	—	—
Anteroposterior diameter of shaft at above position----------	90	90	—	—	—	—	—
Greatest transverse width of distal end (normal to articular surface)----------	272	295	—	—	—	—	—
Greatest width across condyles (normal to line drawn between posterior tips of condyles)----------	247	ca.263	—	—	—	—	—
Least circumference of shaft--------	383	404	—	—	—	—	—
Scapula							
Greatest length from coracoid process to top of scapula, along axis of spine----------	897 (824)	—	(771)	—	—	—	—
External distance from inner border of glenoid cavity to top of spine----------	864 (786)	—	(729)	—	—	—	—

TABLE 3.—Continued

	Mammut americanum[2]				*Mammuthus* sp.[3]		
	K	S	P	R	C1	S/R	P r
Greastest anteroposterior length of glenoid cavity	209	—	211	233	—	—	—
Greatest transverse width across glenoid cavity	131	—	134	150	—	—	—
Humerus							
Greatest length (greater tubercle to tip of lateral condyle)	886	—	—	—	—	—	—
Distal end, transverse width	276	313	—	—	—	—	—
Distal end, width across condyle facets	224	255	—	—	—	250	—
Distal end, anteroposterior depth (of medial condyle)	198	231	—	—	—	213 + mx.220	—
Least transverse diameter of shaft, normal to plane of anterior edge of distal condyles	125	143	—	—	—	—	—
Anteroposterior diameter of shaft, perpendicular to point to least diameter and normal to posterior face of shaft	117	120	—	—	—	—	—
Least circumference of shaft	396	443	—	—	—	—	—
Ulna							
Total length	737	—	—	—	—	—	—
Proximal depth, normal to line drawn between tips of radial and coronoid processes, taken at right angles to main axis of shaft	297	344	—	—	—	291	—
Least thickness, posterior surface of semilunar notch (at median ridge) to Margo dorsalis	168	177	—	181	—	184	—
Width, in plane of articulation, across radial and coronoid proceses (floor of semilunar notch)	235	251	—	274	—	250	—
Least transverse diameter of "neck" of olecranon (measured from above)	60	81	—	84	—	91	—
Greatest width across radial process	85	86	—	90	—	96	—
Greatest width across coronoid process	155	119	—	ca.136	—	112	—
Length of olecranon, from inner semilunar notch to greatest expansion of olecranon process	210	226	—	—	—	202	—
Least transverse width of shaft	104	110	—	—	—	—	—
Least circumference of shaft	340	349	—	—	—	—	—
Radius				Misc.			
Greatest length	651	—	—	626	—	—	—
Proximal end, long diameter	113	—	—	112	—	—	—
Width of shaft at middle (normal to flat side)	54	—	—	51	—	—	—
Distal end, greatest width	163	—	—	151	—	—	—

1. mx, maximum estimated measurement; brackets () indicate measurements taken without superior epiphysis in position.
2. K, Kolarik Mastodon (71.980.50); S, Stroh Mastodon (71.983.73); P, Place Mastodon (71.983.74); R, Reeker Mastodon (71.976.36); Misc., radius Cat#: 71.983.76.
3. C1, large *Mammuthus* tibia (71.983.71); S/R, Swanson/Reichart Mammoth loan; Pr, small Mammoth bones (71.983.72).

Abbreviations used: L, left; R, right; I,C,P,M, upper incisor, canine, premolar and molar, respectively; i,c,p,m, lower teeth; DP,dp, upper and lower deciduous premolars, respectively, vertebrae: C-, cervical, T-, thoracic, L-, lumbar; ribs: L#, left rib, R#, right rib; Mc, Mt, Metacarpal, metatarsal; mm., millimeters; m, meters; mx., maximun estimated measurement; ISM, Indiana State Museum; Cat#, ISM catalogue number; SNA, specimen not apparent; B.P., Before Present (1950 A.D.).

Systematic List of Specimens and Records

Data is presented in four categories: I. Documented specimens; II. Records that cannot be matched with specimens; III., Loans: for exhibition or study and IV., Undocumented specimens. Many of the specimens described by Hay (22, 23) are now lost, or are not apparent among similar materials (SNA).

I. Documented Specimens

Castoroides ohioensis, Giant Beaver

CAT#: 71.981.71 LOCALITY: Boone Co., IN; on the farm of Jas. A. Pratt, near Jamestown. OCCURRENCE: Jaws found in earth thrown out by dredging machine in 1909. MATERIALS: L,R, dentaries with all molars; incisors broken off (Fig.1). DONOR: A.E. Deatley, Lizton. PUBLISHED RECORDS: (6; 22; 23; 28).

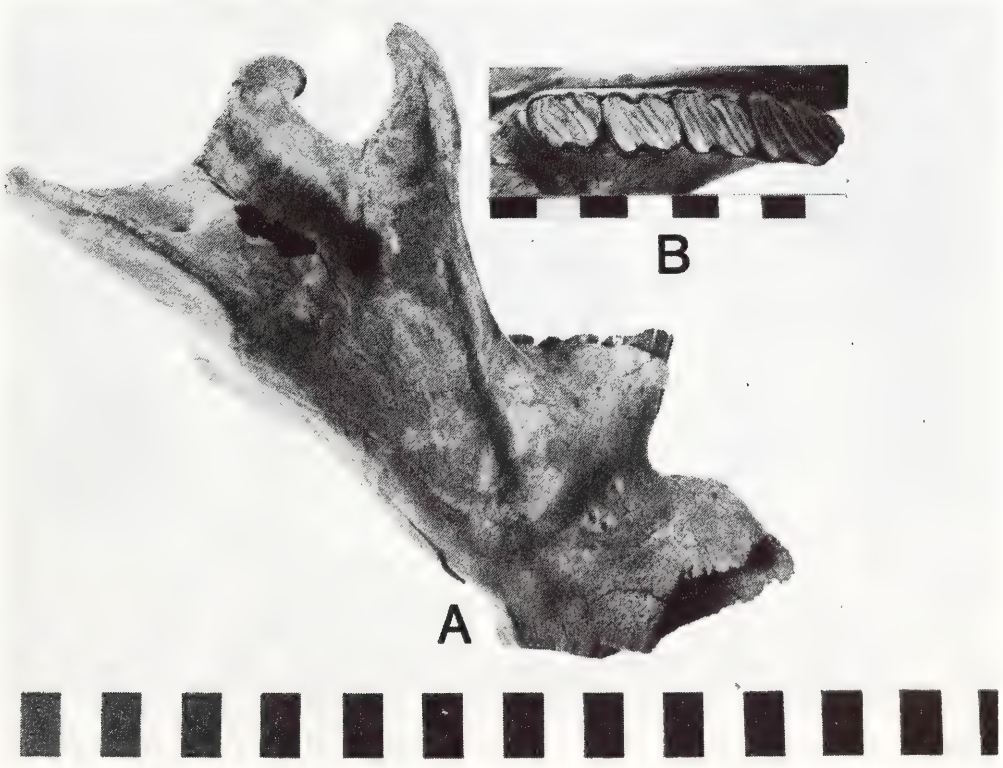


FIGURE 1. *Right dentary of* Castoroides ohioensis *(71.981.71), Boone Co., IN. A, lateral view. B, occlusal view of toothrow. Scale in centimeters.*

Ursus americanus amplidens Pleistocene Black Bear

CAT#: 71.981.14 LOCALITY: Parker's Pit Cave, NE1/4/NW1/4/SE1/4, Sec. 36, T3S, R2E, Corydon West Quad., Harrison Co., IN. OCCURRENCE: Bones partically encased in flowstone, deep within cave. MATERIALS: Partial skeleton, heavily

fragmented; several teeth. DONOR: Greg McNamara, Oct. 9, 1981. PUBLISHED RECORDS: (68). COMMENTS: Radiocarbon age of 29,970± 1290 years B.P. (UGa-4741); materials under study by the author.

Mammut americanum, American Mastodon

1. CAT#: 71.981.70 LOCALITY: Northwestern Orange Co., IN. OCCURRENCE: Materials found "in a valley and about 4.5 feet below the surface". MATERIALS: L mandible with m3. Hay recorded 3 teeth in the jaw in 1912. DONOR: Marion F. Mathers, October 13, 1905 (found in 1903). PUBLISHED RECORDS: (22; 23).

2. CAT#: 71.981.69 LOCALITY: Found near Danville, ?Illinois. OCCURRENCE: Unknown. MATERIALS: Very worn, fragmented molar. DONOR: Dr. Vinnage. PUBLISHED RECORDS: (22; 23). COMMENTS: Hay (22) records a worn m2 as being from near Danville, IN; the old label attached to the specimen, however, appears to indicate Danville, Illinois.

3. CAT#: 71.983.73 LOCALITY: ?LaGrange Co., IN.; unearthed near Stroh. OCCURRENCE: Unknown. MATERIALS: L humerus, distal 1/2; R ulna, proximal 1/2; L McIII; L McIV; R femur; R tibia (Fig. 2); R fibula; vertebra L-1; sacrabra

FIGURE 2. *Proboscidean tibiae in the ISM collection.* Mammut americanum*: A, Kolarik locality, L tibia (71.980.50); B, Place locality, R tibia (71.983.74); C Stroh locality, R tibia (71.983.73); D,* Mammuthus *cf.* primigenius*, locality unknown, R tibia (71.983.72); E,* Mammuthus jeffersonii*, Swanson/Reichart loan, L tibia; F.* Mammuthus *cf.* columbia/imperator*, locality unknown, L tibia (71.983.71). Scale in centimeters.*

no. 1; caudal vertebra; Rib L#6, proximal 2/3. DONOR: Loaned, Wabash Portland Cement Co., July 28, 1925. PUBLISHED RECORDS: (30). COMMENTS: A tooth was originally included; it cannot be located (SNA).

4. CAT#: 71.967.41 LOCALITY: Dubois Co., IN. OCCURRENCE: Found in White River at Haysville, Feb., 1967. MATERIALS: RM3 in maxilla portion. DONOR Virgil Carroll and Nelson Cohen, July 12, 1967 (found by Tom Obsborne). PUBLISHED RECORDS: Unknown.

5. CAT#: 71.976.36 LOCALITY: SE1/4/NE1/4/SW1/4, Sec. 18, T20N, R8E, Anderson North Quad., Madison Co., IN. OCCURRENCE: Skeleton disturbed while excavating a gravel pit. Bones occurred in mollusk-rich blue clays, overlain by peat (personal communication, Martha Reeker, Nov. 28, 1983). Museum staff recovered bones from spoil heaps, along with elements of a White-tailed Deer (71.983.95) and Canada Goose (71.893.96). MATERIALS: Fragmented skull with LM3, heavily worn RM2, anterolateral root of LM2; ?jugal section; styloid process; fragments of tusk; thyro-hyoid; T-2 spine, T-4, T-6 (or 7, 8), T-7 (or 8,9), T-9 (or 10-11), T-ca.14 (neural arch), T-ca.16 (centrum), T-ca.17; indet. neural arch; neural spine epiphysis, anterior thoracic vertebra; L#1, L#2, L#6 (or 7; proximal 3/4), L#9 (or 10,11; proximal 2/3), L#ca. 15 (or 16, 17; proximal end), R#4, R#ca.6 (or 7,8,9; distal 1/3), R#ca.8 (or 9), R#ca.9 (or 10; proximal 1/4), 3 sections of rib; R scapula; R ulna, proximal end; ?ulna, proximal fragment; proximal epiphysis section of femur head; patella; 2 medial phalanges. DONOR: Mr. and Mrs. Noel Reeker, Spetember 28, 1976. PUBLISHED RECORDS: Unknown. COMMENTS: Local residents retained some of the teeth (RM3 and tusk tip) and bones.

6. CAT#: 71.980.50 LOCALITY: SE1/4/SW1/4/SE1/4, Sec. 36, T32N, R2W, Bass Lake Quad., south-central Starke Co., IN. OCCURRENCE: Skeleton discovered while digging a pond in a bog area. The partially articulated bones occurred in a sandy muck overlying mollusk-rich, blue calcareous clays. Plant macrofossils and fish bones were associated, as well as a caribou antler (71.980.50.154), of uncertain context. MATERIALS: Much of the skeleton of one individual, lacking skull, jaws, anterior vertebral column and parts of the R rear leg (Fig. 2). DONOR: Andrew Kolarik, Aug. 12, 1980. PUBLISHED RECORDS: (11;12). COMMENTS: A major report, including radiocarbon dates, pollen profiles, and a description of the vertebrates, is in progress.

7. CAT#: 71.981.91 LOCALITY: Wayne Co., IN.; found in the Whitewater Valley near Richmond. OCCURRENCE: Unknown. MATERIALS: LM3. DONOR: Ruth Kellum-Dinsen and Robert W. Kellum, Nov. 12, 1981; found in mid-1800's by Jesse Kellum. PUBLISHED RECORDS: Unknown.

8. CAT#: 71.981.94.1 LOCALITY: North of Crawfordsville, Montgomery Co., IN. OCCURRENCE: Found in "gravely" sediments in a ditch during construction of interstate I-74 in the 1960's. MATERIALS: Lm1 (possibly Ldp4). DONOR: Jack Householder, Dec. 29, 1981. PUBLISHED RECORDS: Unknown.

9. CAT#: 71.983.74 LOCALITY: SW1/4/SW1/4/SE1/4, Sec. 15, T35N, R1W, Hamlet Quad., St. Joseph Co., IN (1 1/2 miles W.N.W. of Walkerton). OCCURRENCE: Bones removed by owner while digging a pond; backfill piles were graded, and the site is now unapparent. Bones may have occurred in the peat/loam levels that had overlain the mollusk-rich, calcareous clays (with some fish bone). MATERIALS: Axis; C-3, C-4, C-6, C-7; T-1, T-2, T-4 (or 5), T-5 (or 6), T-6 (or 7), T-7 (or 8,9,10), T-8 (or 9,10,11), T-ca.13, T-ca.14, T-ca.16, T-ca.17; L-1, L-2, L-3, 3 anterior caudals; ribs: L#2, L#5, L#6, L#7 (or 8; proximal 1/2), L#ca.8, L#ca.10 (or 11-14; distal 1/2), L#ca.11 (or 12; proximal 1/2), L#.13 (or 14,15), L#ca.15 (or 16,17; proximal 1/2), L#ca.17 (or 18,19; proximal 1/2), R#1, R#2, R#3, R#4, R#5, R#6 (or 7; distal 1/2), R#ca.8 (proximal 1/3), R#ca.9, R#ca.10, R#ca.11 (or 12), R#ca.12 (or 13,14; proximal 2/3), R#ca.13 (or 14,15; proximal 1/2), R#ca.14 (or 15; proximal 1/3), R#ca. 15 (or 16), R#ca.17 (or 18,19); sternebra (manubrium); R scapula; McI; L,R McIII; L,R McIV; L,R McV; L,R cuneiform; R magnum; L innominate, acetabular area with rami sections; patella; R tibia (Fig. 2); R calcaneum; R astragalus; MtI; R MtIII; R MtV; 2 proximal phalanges. DONOR: Elburt F. Place, Sept. 27, 1982; secured by Gary D.

Ellis, Dept. of Historic Preservation and Arthur Mirsky, Dept. of Geology, Indiana-Purdue University, Indianapolis. PUBLISHED RECORDS: Unknown.

Mammuthus sp., Mammoth

1. CAT#: 71.981.38 LOCALITY: Morgan Co., IN.; 1 1/2 miles southeast of Monrovia. OCCURRENCE: Found on a gravel bar in Sycamore Creek. MATERIALS: Rm1 (or 2), posterior portion. DONOR: David M. Hobson, Jan. 11, 1911. PUBLISHED RECORDS: (22; 23; 38). COMMENTS: Hay (22) incorrectly locates Sycamore Creek; it is southeast of Monrovia (Hay, 1923, is correct). Hay records the tooth as a Rm3; the tooth that appears to fit the description is a Rm1 (or 2). The specimen was unlabeled.

2. CAT#: 71.981.40. LOCALITY: Randolph Co., IN.; near Windsor. OCCURRENCE: Found in bed of Stoney Creek. MATERIALS: Rdp4 (or Rm1). DONOR: S.B. Templin, Winchester, IN., Aug. 20, 1983. PUBLISHED RECORDS: (22; 23). COMMENTS: Hay (23) refers to a Rdp3 (now regarded as dp4) or m1, as being in the collection at Earlham College; earlier (22) he referred the Windsor specimen to a Rm3 at the State Museum. The Rdp4, unlabeled, fits Hay's description. There are no records of the Windsor specimen at Earlham College (John Iverson, Director Joseph Moore Museum, oral communication, Nov. 28, 1983).

3. CAT#: 71.981.45 LOCALITY: Vigo Co., IN,; on a farm 3 1/2 miles north of Terre Haute. OCCURRENCE: Found at a depth of 18 feet. MATERIALS: L m3. DONOR: Earl Conover (found 1896 on the farm of Aaron Conover). PUBLISHED RECORDS: (22; 23; 38;). COMMENTS: The specimen was unlabeled; several lamellae are missing from the mid-section of the tooth.

4. CAT#: 71.967.22 LOCALITY: NE 1/4/SW1/4/SW1/4. SEc. 20, T35N, R13E, Waterloo Quad., Dekalb Co., IN. OCCURRENCE: Discovered during construction of interstate I-69. Remains were articulated in mollusk-rich, calcareous clays 8-10 feet below the surface. Jack Householder, who excavated the bones, believes that much of the missing skeleton may have been disturbed during previous installation of drainage tiles (personal communication, Nov., 1983). Other bones may have been located by probing 60-100 feet to the northeast, but were not excavated. MATERIALS: axis, C-6, C-7; T-1 through T-15; ribs: L#1 through L#12, L#13 (proximal 3/4), L#14 through L#17, R#1 through R#9, R#11, R#12, R#15, R#17; sternebra; superior epiphysis of R scapula. DONOR: Elbert Forest; secured on highway right-of-way by Jack Householder, 1967. PUBLISHED RECORDS: Unknown. COMMENTS: Identified as *Mammuthus* sp. by the author.

5. CAT#: 71.968.83.55 LOCALITY: Madison Co., IN. OCCURENCE: Unknown. MATERIALS: RM1 (or RDP4). DONOR: Earl Townsend, Dec. 24, 1968; found in 1841. PUBLISHED RECORDS: Unknown.

6. CAT#: 71.981.36 LOCALITY: NW 1/4/SW1/4/NW1/4, Sec. 21, T19N, R5E, Riverwood Quad., Hamilton Co., IN. OCCURRENCE: Found in White River bottom. MATERIALS: Lm3. DONOR: Mr. and Mrs. Leland S. Gordon, Dec. 31, 1975; secured by Jack Householder. PUBLISHED RECORDS: Unknown.

7. CAT#: 71.981.42 LOCALITY: NW 1/4, Sec. 12, T18N, R4E, Noblesville Quad., Hamilton Co., IN. OCCURRENCE: Found in gravel pit. MATERIALS: Lm3, anterior 1/2. DONOR: Mr. Beaver, 1978-79; secured by Jack Householder. PUBLISHED RECORDS: Unknown. COMMENTS: Posterior 1/2 of tooth retained by owner.

Mammut americanum, American Mastodon/*Mammuthus* sp., Mammoth

1. CAT#: 71.983.88 LOCALITY: Orange Co., IN; unearthed near Orleans. OCCURRENCE: Unknown. MATERIALS: Section of tusk. DONOR: Unknown.

PUBLISHED RECORDS: This may be the tusk referred to by Hay (22). COMMENTS: This tusk also fits the description of the Belt Railroad specimen (22).

2. CAT#: 71.983.85 LOCALITY: Marion, Grant Co., IN. OCCURRENCE: Found in Boots Creek, south of the 14th Street. MATERIALS: 2 ribs: L#7 (or 8,9); R#4. DONOR: R.E. Hulley, Sept. 24, 1923. PUBLISHED RECORDS: (29).

3. CAT#: 71.983.87 LOCALITY: ?Jasper Co., IN. OCCURRENCE: Unknown. MATERIALS: Axis centrum (juvenile). DONOR: Dr. Loughridge, Rensselaer, Jasper Co., IN. PUBLISHED RECORDS: Unknown. COMMENTS: Specimen had label affixed.

Odocoileus virginianus, White-tailed Deer

CAT#: 71.983.95 LOCALITY: Reeker Mastodon Locality (71.976.36; see above). MATERIALS: Antler portion; 2 antler tines; R scapula; R humerus; R radius; L tibia; R Mt, proximal section and 2 Mt shaft sections. PUBLISHED RECORDS: None.

Rangifer tarandus, Caribou

CAT#: 71.980.50.154 LOCALITY: Kolarik Mastodon Locality (71.980.50; see above). OCCURRENCE: Found in sediments ?below Mastodon. Antler removed by Andrew Kolarik when digging pond, after completion of Mastodon dig. Stratigraphic position uncertain. MATERIAL: R antler, lacking most of terminal tine. PUBLISHED RECORDS: (12).

Cervus elaphus, Wapiti

CAT#: 71.981.72 LOCALITY: ?Jasper Co., IN. OCCURRENCE: Unknown. MATERIALS: R antler, basal section. DONOR: Dr. Loughridge, Rensselaer, Jasper Co. PUBLISHED RECORDS: (21; 22; 23; 38). COMMENTS: There is no evidence to presume that the antler is of Pleistocene age as suggested by Lyon (38).

Branta canadensis, Canada Goose

CAT#: 71.983.96 LOCALITY: Reeker Mastodon Locality (71.976.36; see above). MATERIALS: L humerus shaft section. PUBLISHED RECORDS: None.

II. Records that Cannot be Matched with Specimens

Castoroides ohioensis, Giant Beaver

LOCALITY: Madison Co., IN.; found near Summitville. OCCURRENCE: Unknown. MATERIALS: R I in premaxilla. DONOR: T.F. Cartwright. PUBLISHED RECORDS: (6; 22; 23; 38). COMMENTS: Specimen not in ISM collections.

Mammut americanum, American Mastodon

1. LOCALITY: Southern Jackson Co., IN: Judah's Creek (a branch of Mill Creek). OCCURRENCE: Found on creek bank. MATERIALS: "Large molar tooth". DONOR: James Duncan. PUBLISHED RECORDS: (10; 22; 23). COMMENTS: Other bones disintegrated upon exposure. SNA

2. LOCALITY: Marion Co., IN; at Pennsylvania and 30th streets, Indianapolis. OCCURRENCE: Recovered by workmen while excavating for a sewer. MATERIALS: Rm3. DONOR: Charles Dennis. PUBLISHED RECORDS: (22; 23). COMMENTS: SNA; 71.981.64 might possibly be the tooth.

3. LOCALITY: Putnam Co., IN; found near Greencastle. OCCURRENCE: Unknown. MATERIALS: Rm3. DONOR: John G. Sweeney. PUBLISHED RECORDS: (22; 23). COMMENTS: SNA; 71.983.62 might possibly be the tooth.

4. LOCALITY: From near Greenfield, ?Hancock Co., IN. OCCURRENCE:

Unknown. MATERIALS: Two "Mastodon teeth". DONOR: Lewis A Kiefer, March 7, 1927. PUBLISHED RECORDS: Unknown. COMMENTS: SNA.

5. LOCALITY: LaPorte Co., IN. OCCURRENCE: Unknown. MATERIALS: "6 mastodon bones from LaPort Co.". DONOR: Miss Oran Hay, Sept. 16, 1929; from the collection of Frank Hay, Bass Lake. PUBLISHED RECORDS: (32). COMMENTS: SNA.

6. LOCALITY: Unknown. OCCURRENCE: Unknown. MATERIALS: "3 pieces mastodon teeth". DONOR: William Hauck, Sept. 19, 1930; collection of John A. Bense, 5 miles south of Greencastle, IN. PUBLISHED RECORDS: (33). COMMENTS: SNA; might possibly include 71.981.78 fragments.

7. LOCALITY: Whitley Co., IN.; Blue River Valley. OCCURRENCE: Found in gravel pit. MATERIALS: "Mastodon tooth". DONOR: V.Y. Chittick. PUBLISHED RECORDS: Unknown. COMMENTS: SNA.

Mammuthus sp., Mammoth

1. .LOCALITY: Carroll Co., IN.; found near Bringhurst. OCCURRENCE: Unknown. MATERIALS: m3. DONOR: John Flora. PUBLISHED RECORDS: (22; 23; 38). COMMENTS: SNA: 71.981.34 has some similarities to the tooth described by Hay (22; 23).

2. LOCALITY: Jackson Co., IN.; near Brownstown. OCCURRENCE: Taken from a stream. MATERIALS: 2 teeth; 2 tusks; part of lower jaw; fragments. DONOR: Recovered by Ralph Esarey and assistants, Bloomington; donated Nov. 23, 1929. PUBLISHED RECORDS: (33). COMMENTS: SNA.

3. LOCALITY: Unknown. OCCURRENCE: Unknown. MATERIALS: "Mammoth Tooth." DONOR: Clint Perry, Indianapolis. PUBLISHED RECORDS: (28). COMMENTS: SNA.

4. LOCALITY: Unknown. OCCURRENCE: Unknown. MATERIALS: "Portion of the tooth of a mammoth." DONOR: J.M. Larsh, Indianapolis. PUBLISHED RECORDS: (28). COMMENTS: SNA.

Mammut americanum, American Mastodon/*Mammothus* sp., Mammoth

LOCALITY: Marion Co., IN.; near the Belt Railroad. OCCURRENCE: Unknown. MATERIALS: Section of tusk about 600 mm. long and 100 mm. in diameter. DONOR Americus Fish. PUBLISHED RECORDS: (22). COMMENTS: Hay (22) identified the tusk as that of a Mastodon. The description is similar to that of 71.983.88, thought to be from Orange Co. SNA.

Cervus elaphus, Wapiti

1. LOCALITY: Newton Co., IN.; near Foresman. OCCURRENCE: Unknown. MATERIALS: "1 antler, length about 1200 mm. and base diameter 94 mm.; 5 tines." DONOR: D.E. Howe, 1884. PUBLISHED REOCRDS: (21; 22; 23; 38). COMMENTS: Specimen not in ISM collection. There is no evidence to presume the antler to be of Pleistocene age, as suggested by Lyon (38).

2. LOCALITY: Marion Co., IN.; at west Morris Street on Eagle Creek. OCCURRENCE: Recovered 45 feet below the surface by the Kaster Gravel Co. MATERIALS: Antler. DONOR; R.C. Kaster, Sept. 6, 1924. COMMENTS: SNA.

?*Odocoileus virginianus*, White-tailed Deer and *Equus* sp., Horse

LOCALITY: Decatur Co., IN. OCCURRENCE: Found in a gravel pit. MATERIALS: "Jaw of a horse and deer antlers". DONOR: McNeely Bros., St. Paul, IN. PUBLISHED

RECORDS: (33). COMMENTS: SNA. Information insufficient to presume Pleistocene age.

III. Records of Loans to ISM: for Study or Exhibition

Mammut americanum, American Mastodon

1. LOCALITY: Marion Co., IN.; north of Raymond Street, Indianapolis. OCCURRENCE: Unknown. MATERIALS: "Mastodon tooth". LOANED BY: A.D. Wixson, Oct. 16, 1924. PUBLISHED RECORDS: (30). COMMENTS: Museum records locate the tooth south of Raymond Street.

2. LOCALITY: Dekalb Co., IN.; Keyser Township, 2 miles south of Garrett. OCCURRENCE: Found while probing ground for drain tile. Bones associated with wood, in a marly clay. MATERIALS: Partial skeleton. LOANED BY: Found on highway right-of-way in 1934. PUBLISHED RECORDS: (34; 38; 72). COMMENTS: Owner later claimed the skeleton.

3. LOCALITY: ?Owen Co., IN.; near Gosport. OCCURRENCE: Plowed up in field. MATERIALS: RM2. LOANED BY: William Stapelkemper, 1982 to Gary Ellis, archaeologist, Division of Historic Preservation. PUBLISHED RECORDS: Unknown. COMMENTS: The tooth, examined by the author, had a length of 110 mm. and a width across the metaloph of 83.5 mm.

Mammuthus jeffersonii, Jefferson's Mammoth

LOCALITY: SW 1/4/SW 1/4/NW 1/4, Sec. 21, T21N, R7E, Alexandria Quad., Masidon Co. IN. (1 1/2 miles S.W. of Orestes). OCCURRENCE: Fragmented bones were discovered in landfill 1 mile west of Alexandria (SW 1/4/SE 1/4/SE 1/4, Sec. 15, T21N, R7E, Alexandria Quad., Madison Co.) by Vern Swanson. The fill apparantly came from the excavation for a pond on the Reichart property, though no bones were actually located there. The bones were associated with a clayey silt matrix, including some blackened gravel. Mollusks and other vertebrates were lacking in sediment samples washed through a 1.5 mm. sieve. MATERIALS: Cranial fragments; tusk fragments; 2 caudal vertebrae; L posterior rib, proximal section; R scapula, glenoid cavity area; R humerus, distal shaft; L humerus, distal articulation; L ulna, proximal articulation; L scaphoid; L lunar; L trapezium; pelvic section, including part of acetabulum; R femur, lateral shaft section; L tibia (Fig. 2); (?)R fibula shaft and many fragments. LOANED BY: Vernon Swanson and Brian Reichart, Dec., 1983. PUBLISHED RECORDS: None. COMMENTS: Materials were conserved, photographed and measured at the ISM. Assigned to *M. jeffersonii* on length of tibia (743 mm.; Table 3).

IV. Undocumented Specimens

Mammut americanum, American Mastodon

Fourteen undocumented teeth and their measurements are included in Table 1. Many are quite fragmentary. CAT#: 71.981.60 (LM3) and 71.981.63 (LM2) are from the same individual.

ADDITIONAL MATERIALS: CAT#: 71.981.78, 4 fragments of teeth;

CAT#: 71.983.83, atlas; CAT#: 71.983.76, R radius.

Mammuthus sp., Mammoth

Fifteen undocumented teeth and their descriptions are included in Table 2. Many are just fragments. Three tooth sections (71.981.52, 71.981.53 and 71.983.68) may be from the same individual.

ADDITIONAL MATERIALS:

1. CAT#: 71.983.69 MATERIALS: 3 separated lamellae of a tooth.

2. CAT#: 71.983.71 MATERIALS: atlas; lumbar vertebra, L-2 (possibly L-1); L

dentary, outer face section; L tibia (Fig. 2) and Lm2 (71.981.37). COMMENTS: The immense bones suggest *Mammuthus columbi* or *imperator*. The tooth characters, however, indicate a more "progressive" Mammoth, perhaps a European form. The remains appear not to be from Indiana.

3. CAT#: 71.983.72 MATERIALS: R tibia (Fig. 2); R fibula; R calcaneum; R astragalus. COMMENTS: The small elephant bones are probably from *Mammuthus primigenius*; they are probably not from Indiana.

Mammut americanum, American Mastodon/*Mammuthus* sp., Mammoth
CAT#: 71.983.86 MATERIALS: rib R#6 (or 7, 8, 9). EXPENDABLE MATERIALS: A L femur diaphysis, glenoid cavity area of a scapula, fragmented humerus, thoracic vertebra and several fragments were too poorly preserved and documented to be catalogued into the collection.

Family Megalonychidae/Mylodontidae, Sloth sp.
CAT#: 71.983.75 MATERIALS: L rib, posterior area of column. COMMENTS: *Megalonyx jeffersonii* and *Glossotherium harlani* are the sloths of the region (26). The rib compared well with, but was from a smaller individual than the large *M. jeffersonii* cast skeleton (of the Darke Co., Ohio specimen) in the Cincinnati Museum of Natural History.

Other Materials

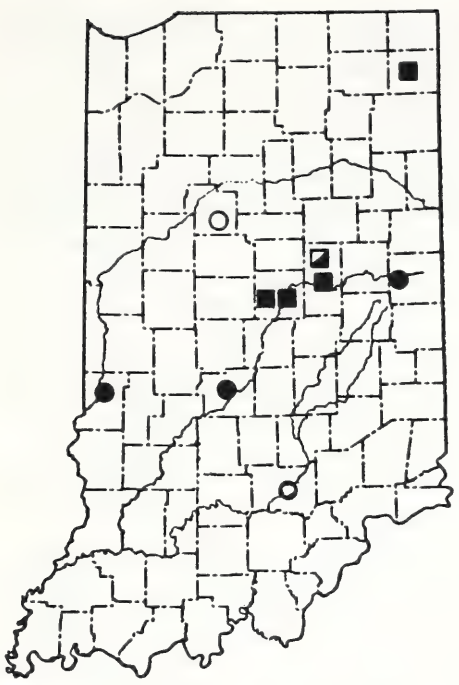
A left dentary of a horse (71.981.74) and several bovid bones (cf. *Bison bison*), thought to be of Holocene age, are not treated here.

Discussion

The ISM Pleistocene vertebrate collection consists primarily of the remains of large mammals, especially those of Mastodon and Mammoth. Proboscidean localities are summarized in Figures 3 and 4.

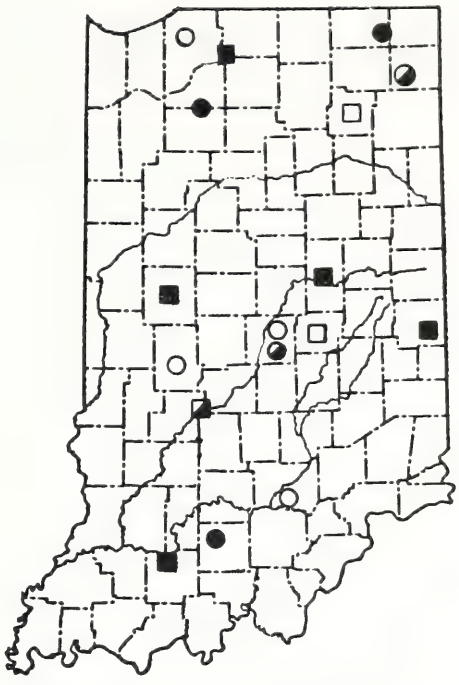
Most of the Mastodon (*Mammut americanum*) teeth were of the medium and small size range (Table 1) when comparing M3/m3 measurements with those from Missouri (71) and from the collections at the University of Michigan (73). Two teeth (71.976.36.1; 71.981.68), however, were of large size. The Reeker Mastodon had the largest bones, followed by the Stroh, Kolarik and Place Mastodons (Table 3; Figure 2). In general, limb bones compared with the medium size of those from Missouri (71). Teeth and bones from the Christensen Mastodons, Hancock Co., IN. were also from small to medium-sized individuals (19). The Mastodon appears to display sexual dimorphism as well as geographic variation in size (19).

North American mammoths have had a chaotic taxonomic history. Hay (22; 23), using the dental criteria of earlier workers, separated regional mammoths into *Mammuthus primigenius* (Woolly Mammoths) and *M. columbi* (Columbian Mammoths) (58). In 1922 Osborn reassigned the specimens formerly designated as *M. columbi* (with vague characters of the type specimen) to a new species, *M. jeffersonii* (Jefferson's Mammoth, type specimen from Jonesboro, IN) (57). More recently, regional mammoths once assigned to *M. primigenius* as well as *M. columbi* are all believed to be *M. jeffersonii* (26; 40; 73; letter, C.T. Madden, Aug. 6, 1981). Some authors consider *M. jeffersonii* to be a progressive subspecies of *M. columbi* (4; 18; 43). Maglio (43) iterates that species delineation is arbitrary in a continuously evolving "species lineage", and that it is more important to assign an individual within the evolutionary sequence.



Mammuthus sp.

FIG. 3



Mammut americanum

FIG. 4

LEGEND

■ Specimen (unpublished) ● Specimen (published)

□ SNA (unpublished record) ○ SNA (published record)

◪ Loan (unpublished record) ◕ Loan (published record)

FIGURE 3. AND 4. *Specimens and records of Mammoths (*Mammuthus *sp.) and Mastodons (*Mammut americanum*) in the collections of (or previously on loan to) the Indiana State Museum. SNA = particular specimen not apparent among similar specimens (no catalogue numbers present).*

The small *Mammuthus primigenius* (shoulder height ca. 2.8 m.) is a late arrival from the Beringia; it inhabited the tundra and conifer areas in northern North American. The M3/m3 had 20-27 plates (P), a lamellar frequency (LF) of 7-12 and an enamel thickness (ET) of 1.0-2.0 mm. (43). *M. jeffersonii*, 3.2-3.4 m. at the shoulder, inhabited the prairies of much of temperate North America; progressive populations had M3/m3 with 24-30P, LF of 7-9 and an ET of 1.5-2.0 (43). *M. columbi* was abundant in many environments in northwestern North America, and western and southern United States (P = 15-22; LF = 4.1-8.3; ET = 1.1-3.4) (41;42). *M. imperator*, the largest North American mammoth (to 4.0 m. at the shoulder) inhabited the southern and southwestern United States; its teeth has fewer plates, a lower LF and thicker enamel than those of *M. columbi*. Specimens occur that are intermediate between all of the species.

Most of the ISM teeth fall within the range of characters of *M. jeffersonii* and *M. primigenius* teeth (Table 2). Because most have characters that approximate the average of *M. jeffersonii*, the only mammoth definitely identified from the region, they probably represent that taxon. Cary Madden, examining photographs, observed that most appeared to represent *M. jeffersonii* (letter, Aug. 6, 1981). *M. primigenius*, however, might possibly be included. A lower molar (71.981.41) with very coarse

characters is assigned to *M.* cf. *columbi*. As taxonomies become more refined, the data presented may allow better assignment to species.

Tibiae (with epiphyseal union completed) fall into three sizes (Fig. 2). The ratio of tibia length (735 mm.) to shoulder height (3.2 m.) of the Jonesboro *M. jeffersonii* (22; 56) is 23%. Accordingly, the Swanson/Reichart tibia (743 mm.) represents an animal of similar size (*M. jeffersonii*), the small tibia (71.983.72) (646 mm.) an animal 2.8 m. (*M.* cf. *primigenius*) and the large tibia (71.893.71) (918 mm.) an animal 4.0 m. (*M.* cf. *columbi/imperator*). The latter two are probably not Indiana specimens. Future work will determine if the Columbian Mammoth once ranged into Indiana.

In overview, most of the materials in the ISM collection are from donations of large "spectacular" bones. Little field recovery was done by staff on undisturbed sites. Because of this, paleoecological interpretations involving radiocarbon dates, pollen analysis, and the interpretation of mollusks, sediments and associated microfauna are lacking (exception: Kolarik Mastodon locality). Little taphonomy can be studied on such disturbed sites to understand how and why the animals accumulated.

What has been recorded is the identifications and locations of the animals; this adds to the knowledge of distribution and abundance. Materials have been given complete listing, indicating the available comparative specimens for future workers. Measurements have been given, and others kept on file, to help establish a data base on the range of variation in size of regional proboscideans.

An up-to-date list of the Pleistocene vertebrates now known from Indiana is appended. The occurrence of Pleistocene vertebrates in Indiana was summarized by Cope and Wortman (1885), Thompson (1886), Hay (1912 and 1923), Moodie (1929) and Lyon (1936) (9; 76; 22; 23; 47; 38). Kurten and Anderson (1980) summarized decades of Pleistocene mammalogy (26). They included, however, few references to Indiana materials. Many new taxa have been recovered since the accounts of Lyon. (1936).

Late Pleistocene faunas are in general composed of extinct, extralocal (taxa occurring out of their modern ranges) and modern resident species, as noted by Lundelius (35) for central Texas. Only extinct and extralocal taxa documented by fossils will be listed for Indiana. Taxa that should have occurred in Indiana, though have not yet been adequatelv documented by fossils (eg. *Bison latifrons*, Giant Bison and *Ursus arctos*, Grizzly Bear) are not included. The list includes locations by county with primary (though not exhaustive) literature. This will enable workers to add the Indiana range data to the total species distribution. Listings preceeded by the number of localities are believed to be complete. A double asterisk (**) follows the names of persons presently studying or supplying information on particular specimens.

Extinct Vertebrates of the Indiana Pleistocene

Mammalia

Family Megalonychidae

Megalonyx jeffersonii, Jefferson's Ground Sloth. 3 LOCALITIES: Daviess (Sparling **, *M.* cf. *jeffersonii*); Martin (1); Vanderburgh (22; 23; 27; 38). A Switzerland Co.record (82) is poorly documented.

Family Dasypodidae

Dasypus bellus, Beautiful Armadillo. 3 LOCALITIES: Daviess (78; 79); Monroe (65; Richards**); Lawrence (Richards**).

Family Castoridae

Castoroides ohioensis, Giant Beaver. Numerous LOCALITIES: (1; 6; 13; 19; 22; 23; 38; 48; 49; 50; 51; 53; 78; 79).

Family Canidae

Canis dirus, Dire Wolf. 2 LOCALITIES: Monroe (54; 60; 81); Vanderburgh (TYPE SPECIMEN: 22; 23; 27; 38).

Family Ursidae

Ursus americanus amplidens, Pleistocene Black Bear. 1 LOCALITY: Harrison (68; Richards**).

Arctodus simus, Giant Short-faced Bear. 1 LOCALITY: Fulton (68; Richards and Turnbull**).

Family Felidae

Panthera onca augusta, Pleistocene Jaguar. 1 LOCALITY: Monroe (54; 60; 81).

Family Machairodontidae

Smilodon fatalis, Sabertooth. 1 LOCALITY: Monroe (54; 60; 81).

Family Mastodontidae

Mammut americanum, American Mastodon. The most numerous of regionally recorded material. Numerous LOCALITIES: (eg. 8; 11; 12; 15; 17; 19; 22; 23; 25; 38; 39; 44; 46; 52; 62; 72; 80; 84).

Family Elephantidae

Mammuthus jeffersonii, Jefferson's Mammoth. All Indiana *Mammuthus* are provisionally assigned to this taxon. Numerous LOCALITIES: (eg. 8; 22; 23; 38; 55; 56; 57, TYPE SPECIMEN; 59; 63; 83; 85).

Family Tapiridae

Tapirus haysii, Hay's Tapir. 1 LOCALITY: Vanderburgh (22; 23; 27; 38).

Family Equidae

Equus cf. *complicatus*, Complex-toothed Horse. 3 LOCALITIES: LaPorte (37; 38); Monroe (60); Vanderburgh (22; 23; 27; 38).

Family Tayassuidae

Platygonus vetus, Leidy's Peccary. 2 LOCALITIES: Lawrence (22; 23; 38); Monroe (54; 60; 81).

Platygonus compressus, Flat-headed Peccary. 3 LOCALITIES: Allen (20); Marion (Munson**); Wabash (9; 22; 23; 38).

Mylohyus nasutus, Long-nosed Peccary. 5 LOCALITIES: Daviess (78; 79); Gibson (TYPE SPECIMEN: 9; 22; 23; 38); Jennings (ulno-radius in the Joseph Moore Museum, Earlham College); Monroe (2 localities: Munson**).

Family Camelidae

Camelops sp., Camel. 1 LOCALITY: Harrison (Richards**).

Family Cervidae

Cervalces scotti, Stag-Moose. 3 LOCALITIES: Allen (14); Pike (69); St. Joseph (16).

Family Bovidae

Bison antiquus, Ancient Bison. 1 LOCALITY: Knox (22; 23; 38; 45).

Symbos cavifrons, Woodland Musk-ox. Several LOCALITIES: (eg. 22; 23; 36; 37; 38; 61; there have been additional recent finds in Knox, Kosciusko, Marion, Owen and Parke counties: Munson**).

Extralocal Vertebrates: Living Taxa that Ranged into Indiana during the Late Pleistocene

Mammalia

Family Talpidae

Parascalops breweri, Hairy-tailed Mole. 3 LOCALITIES: Lawrence (66, probably Holocene); Monroe (2 localities: 60; 66).

Family Soricidae

Sorex arctius, Arctic Shrew. 1 LOCALITY: Harrison (Richards**).

Sorex fumeus, Smoky Shrew (large). 1 LOCALITY: Harrison (67; Richards**).

Family Cricetidae

Oryzomys cf. *palustris*, Marsh Rice Rat. 3 LOCALITIES: Harrison (2 deposits, probably Holocene: 65); Monroe (65); Vanderburgh (Holocene: 2; 3).

Clethrionomys gapperi, Boreal Red-backed Vole. 4 LOCALITIES: Daviess, Harrison (2 localities) and Lawrence: (Richards**).

Phenacomys cf. *intermedius*, Heather Vole. 3 LOCALITIES: Lawrence, Harrison (Richards**); Parke (Fay**).

Family Cervidae

Rangifer tarandus, Caribou. 2 LOCALITIES: Hancock (19, 46); Starke (12).

Family Bovidae

Ovibos moschatus, Muskox. 1 LOCALITY: Wayne (22; 23; 38).

Extralocal Vertebrates: Living Species with Reduced Ranges in Indiana since the Late Pleistocene.

Reptilia

Family Colubridae

Opheodrys vernalis, Smooth Greensnake. 1 LOCALITY: Monroe (24).

Family Anguidae

Ophisaurus cf. *attenuatus*, Western Ophisaur. 1 LOCALITY: Greene (Richards**). Age unknown.

Mammalia

Family Talpidae

Condylura cristata, Star-nosed Mole. 1 LOCALITY: Daviess (Richards**).

Family Geomyidae

Geomys cf. *bursarius*, Plains Pocket Gopher. 3 LOCALITIES: Harrison, Lawrence (Richards**); Monroe (60).

Family Sciuridae

Spermophilus tridecemlineaus, Thirteen-lined Ground Squirrel. 2 LOCALITIES: Lawrence (Richards**); Monroe (66).

Family Cricetidae

Neotoma floridana, Eastern Woodrat. Numerous LOCALITIES: (5; 60; 64); new localities: Jefferson, Jennings and Shelby counties (Richards**).

Family Mustelidae

Martes pennanti, Fisher. 3 LOCALITIES: Daviess (78); Harrison (Richards**); Tippecanoe (18th century: Martin**).

Spilogale putorius, Spotted Skunk. Several LOCALITIES: (5; 60; 64; 66; Richards**). Some are of Holocene age.

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Survey of Nesting Raptors in Northeastern Indiana

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The Study Area

Areas within the twelve northeastern Indiana counties of Elkhart, LaGrange, Steuben, Kosciusko, Noble, DeKalb, Whitley, Allen, Wabash, Huntington, Wells and Adams were surveyed for raptors (birds of the orders Falconiformes and Strigiformes). The topography of this region varies from the steep knob and kettle terrain of Steuben county to the flat lands of Huntington and Wells counties.

These are primarily agricultural lands. Even Allen county, which has the greatest urban development, is over seventy percent agricultural land. In general, the more northern of these counties are more wooded, but all of them contain many second and third growth woodlots of various sizes.

The Study Method

Twenty-seven sites were visited. These were: Acres along the Wabash Nature Preserve, Beechwood Nature Preserve, Lloyd W. Bender Nature Preserve, Chain-O-Lakes State Park, Crooked Lake Nature Preserve, Fogwell Forest Nature Preserve, Foxfire Wood, Fox Island Nature Preserve & County Park, Franke Park, Grider's Wood Nature Preserve, Hanging Rock Natural Area, Lindenwood Environmental Study Area, Mengerson Nature Reserve, Merry Lea Nature Preserve, Olin Lake Nature Preserve, Pigeon River State Fish & Game Area, Pokagon State Park, Potawatomi Nature Preserve, Albert D. Rodenbeck Nature Preserve, Ropchan Memorial Nature Preserve, Ropchan Wildlife Refuge Nature Preserve, Salamonie State Forest, Edna W. Spurgeon Nature Preserve, Tamarack Bog Nature Preserve, Quabache Recreation Area, Huntington Reservoir Recreation Area, and private properties in various counties. They varied in size from the one-half acre Hanging Rock Natural Area to the 9,136 acre Pigeon River State Fish and Game Area. The survey technique consisted of walking through the prime habitat in a given site, looking for nests and areas of concentrated excrement, and listening for calls of adults or young birds. This technique allowed for good coverage of small to medium (100 acre) sites. In the large sites, such as the Pigeon River Fish and Game Area, Pokagon State Park, or Chain-O-Lakes State Park, individual wooded areas were surveyed, but the entire site was not. Whenever possible, park naturalists, state biologists, or local bird watchers were consulted about the current status of nesting raptors. These people were also able to provide information about past (1972-1983) nesting records.

Enroute to the survey sites, the areas along the highways were scanned for nesting raptors. The nest of buteonine hawks on private lands were often located in this way. These techniques were most effective for locating stick nests. Hole nests were much more difficult to find; hence, they were probably often missed.

The Historic Record

The raptors have not been intensively studied in the past. In 1898 Butler reported on the entire state of Indiana, as did Mumford and Keller in 1975 and Keller, et al. in 1979. The only detailed study of northeastern Indiana was made by Price (1939,

1962) who entered many Indiana counties while studying the birds of northeastern Ohio from 1915 to 1962. Table 1 lists the raptors reported as nesting in northeastern Indiana by Butler in 1898; by Price in 1915-1962; and the present study.

TABLE 1. *Raptor nesting records for northeastern Indiana.*

Species	Years		
	1878	1915-1962	1972-1983
Turkey Vulture		X	X
Osprey	X		
Bald Eagle	X	X	
Northern Harrier	X	X	X
Cooper's Hawk	X	X	X
Sharp-shinned Hawk	X		
Red-shouldered Hawk	X	X	X
Broad-winged Hawk		X	X
Red-tailed Hawk	X	X	X
American Kestrel	X	X	X
Barn Owl	X	X	
Eastern Screech Owl	X	X	X
Great Horned Owl	X	X	X
Barred Owl	X	X	X
Saw-whet Owl	X		
Long-eared Owl	X	X	X
Short-eared Owl	X	X	
	15	14	11

In 1898 fifteen raptors were reported as nesting in the survey area. These included the Bald Eagle, the Barn Owl, and probably the Osprey. Butler (1898) reported that the Osprey was found in Steuben, LaGrange, and DeKalb counties in 1890-91 and that it bred throughout its range. Clark and Sipe (1967) reported that Ospreys nested near Lake St. Mary's, Ohio (40 miles east) in the same time period, 1867-1913.

Price (1939, 1962) found fourteen nesting raptors. He did not report the Osprey, the Sharp-shinned Hawk, or the Saw-whet Owl, but added the Turkey Vulture and Broad-winged Hawk.

Results and Conclusions

Nesting records for northeastern Indiana were compiled from my field notes and those of other observers (see acknowledgements below). These records indicated that in the eleven year period 1972-1983 eleven species of raptors nested in northwestern Indiana. The Bald Eagle, Osprey, Sharp-shinned Hawk, Barn Owl, Saw-whet Owl and Short-eared Owl, which nested in early years, were not recorded in this survey. The Northern Harrier was reported as a current breeding bird, but the most recent nest was seen in 1982.

A decline in the number of nesting raptor species in the region can be seen in Table 1. In addition, it is probable that the numbers of raptorial birds in the region have decreased. Of the seventeen species reported as nesting in northeastern Indiana, only the Red-tailed Hawk and American Kestrel were reported as commonly seen in recent years by Tieben, et al. (1978). The Eastern Screech Owl and the Northern Harrier were reported as fairly common. The Northern Harrier is now an uncommon bird in this region, as are the Cooper's Hawk, Red-shouldered Hawk, Broad-winged Hawk, Great Horned Owl, and Barred Owl; the Long-eared Owl is very rare. Therefore, the species nesting in northeastern Indiana may be expected to continue to decline.

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